A biomass size spectrum (BSS) depicts the abundance and distribution of organisms by size classes in an ecosystem. In aquatic ecosystems, the biomass (i.e., aggregate weight) of organisms at each level in the food chain from microscopic phytoplankton to the largest vertebrate animals is nearly equal. Because biomass is near-max, numbers of small organisms greatly exceed numbers of large organisms. Size-specific predation (the largest eat the smaller ones) in aquatic communities maintains the observed biomass size structure and has led to methods for evaluation of biomass-size relationships to characterize the structure and state of ecosystems. To derive BSS, data from monitoring programs on organism abundances must be aggregated into size categories. BSS models can be applied to a broad suite of aquatic biological communities, including estuarine ecosystems larger than Chesapeake Bay.

**Ecological Indicators:** Changes in the slope or other statistical properties of the normalized BSS relative to reference standards or historical benchmarks is an indicator of changes in the abundance and biomass of the suite of organisms in an aquatic ecosystem.

**Ecological Effect/Impact:** Changes in the slope of the normalized BSS can be indicative of changes in the biological community structure, productivity, food-chain efficiency, prey-prey relationships, and effects of environmental variability, fishing, nutrient loading, and habitat change. BSS of stressed ecosystems often have steeper negative slopes. For example, in heavily fished ecosystems larger fish may be reduced in number and biomass. On high zooplankton ecosystems with excess nutrient loading, blooms of microscopic phytoplankton can greatly increase the abundance and biomass of small organisms, leading to stressed conditions such as hypoxia and mortality of larger organisms (e.g., crabs, fish).

**Environmental Application:** BSS can be used by managers to describe long-term effects of stress on the success of restoration efforts in estuaries impacted by human activities. BSS can be applied to a broad suite of aquatic biological communities, not only to selected organisms, and thus can indicate how whole ecosystems are responding to either deterioration or remediation efforts in resource management. BSS can be applied to fisheries management, habitat restoration, improved water quality. Periodic monitoring of sizes and abundances of organisms is required to apply BSS as an indicator.

**New Indicators of Coastal Ecosystem Condition**

Phytoplankton community composition is a gauge of ecological condition and change. Phytoplankton are suspended microscopic algae. They are the primary major producers in estuarine and coastal ecosystems, are fast growth rates, and are sensitive to environmental disturbances. Phytoplankton communities, such as diatoms, dinoflagellates, chrysophytes, cryptomonads each have their own unique diagnostic signatures. For example, chlorophyll-a and carotenoids, are molecules that capture and convert light into chemical energy for powering photosynthesis.

**Ecoindicator Research for the Gulf of Mexico (CEER GOM)**

**Estuarine and Great Lakes (EaGLe) Program**

**PEER Program:** Fractional Estuarine Ecosystem Indicator
University of California–Davis

**CEER GOM Conservation of Estuaries Ecosystem Research for the Gulf of Mexico University of South Carolina

**ASC Program:** Atlantic States Consortium
Pennsylvania State University Washington DC

**ACE INC Program:** Atlantic Coast Environmental Indicators Consortium
University of North Carolina, Chapel Hill

**EPA’s Science to Achieve Results (STAR) Program**

**Coastal Ecosystems**

**Introduction:** Coastal ecosystems, from large estuaries to salt marshes, are recognized for their important ecological function and societal value. In order to understand productivity of the marsh, reduction of water table, erosion, and sea level rise. In some areas, coastal ecosystems have displaced native species, threatening commercially important biological resources by altering habitat and productivity of the marsh. Reduction of water clarity, through increases in suspended sediments and algal blooms, adversely affects the growth of subtidal aquatic vegetation, the nursery grounds for many fish and shellfish. In order to maintain continued degradation and loss of coastal ecosystems services and to plan for their remediation, new indicators are needed that will predict when and where ecosystem degradation and wetland losses will occur. Three ecological indicators of coastal condition are being investigated by researchers with the Atlantic Coast Environmental Indicators Consortium (ACE INC): phytoplankton community composition, salt marsh elevation and plant health, and the size distribution of aquatic organisms (Hofmarcher spectra).
The health and productivity of coastal wetlands are dependent upon the success of the plant life, which in turn is dependent upon the plant’s relationship to sediment, sea level, and the tide. Many coastal marshes depend on sediments supplied by rivers to counteract the effects of land subsidence, sea-level rise, and sediment compaction. In some areas, changes on the land have led to increased sediment supply to coastal wetlands, leading to a decrease in height relative to mean sea level. Where delta levees have been constructed to halt the settling of sediments, marshes have been cut off from their source of sediment, and the net effect is conversion of marsh habitat to open water.

2) RELATIVE ELEVATION AND PLANT HEALTH AS INDICATORS OF COASTAL MARGINAL STABILITY AND PRODUCTIVITY

The health and productivity of coastal wetlands are dependent upon the success of the plant life, which in turn is dependent upon the plant’s relationship to sediment, sea level, and the tide. Many coastal marshes depend on sediments supplied by rivers to counteract the effects of land subsidence, sea-level rise, and sediment compaction. In some areas, changes on the land have led to increased sediment supply to coastal wetlands, leading to a decrease in height relative to mean sea level. Where delta levees have been constructed to halt the settling of sediments, marshes have been cut off from their source of sediment, and the net effect is conversion of marsh habitat to open water.

Vertical elevation is a critical variable that determines the productivity and stability of salt marshes. The long-term existence of the salt marsh depends on the success of the dominant plants, such as Spartina and Juncus, and their close relationship to sediment supply, sea level change, and tidal influence.

Researchers at the University of South Carolina, Columbia, SC, and the Marine Biological Laboratory, Woods Hole, MA have developed two indicators that can be applied to assess the condition of coastal marshes. The first indicator is relative elevation (geophenology) and the other is level of stress of marsh vegetation (physiology).
Ecological Effect/Impact: Changes in phytoplankton community composition are important indicators of estuarine and coastal ecological condition and health because phytoplankton plays a major role in primary production, eutrophication (including harmful algal blooms), nutrient cycling, water quality, and local food webs. Environmental Application: Phytoplankton community composition can serve as an early warning signal of toxic or hypoxia-generating algal blooms. It has proven useful and applicable for evaluating ecosystem and regional responses to environmental stresses, including increased nutrient loads, changes in hydrographic characteristics, and climatic disturbances such as hurricanes and droughts.

Together with the North Carolina Department of Environment and Natural Resources, researchers at the University of North Carolina at Chapel Hill’s Institute of Marine Sciences are using diagnostic photopigments to determine phytoplankton in the Neuse River Estuary, NC. The dates of landfall of the seven major hurricanes that have significantly affected flow and nutrient enrichment since mid-1996 are shown. Figure 2. Changes in phytoplankton community composition are important indicators of coastal and estuarine water quality, and serve as a proxy for overall health and productivity of the ecosystem. Phytoplankton community composition can serve as an early warning signal of toxic or hypoxia-generating algal blooms. It has proven useful and applicable for evaluating ecosystem and regional responses to environmental stressors, including increased nutrient loads, changes in hydrographic characteristics, and climatic disturbances such as hurricanes and droughts. Environmental Application: Phytoplankton community composition can serve as an early warning signal of toxic or hypoxia-generating algal blooms. It has proven useful and applicable for evaluating ecosystem and regional responses to environmental stressors, including increased nutrient loads, changes in hydrographic characteristics, and climatic disturbances such as hurricanes and droughts. Environmental Application: Phytoplankton community composition can serve as an early warning signal of toxic or hypoxia-generating algal blooms. It has proven useful and applicable for evaluating ecosystem and regional responses to environmental stressors, including increased nutrient loads, changes in hydrographic characteristics, and climatic disturbances such as hurricanes and droughts.

Environmental Application: These indicators offer a cost-effective alternative for assessing risk for wetland loss, as well as monitoring the condition of coastal wetlands and the success of restoration efforts. Resource managers can use this information, for example, to apply mitigation techniques for adjusting sediment supply for wetlands at high risk of inundation.
Ecological Effect/Impact: Changes in phytoplankton community composition are important indicators of estuarine and coastal ecological condition and health because phytoplankton plays a major role in primary production, eutrophication (including harmful algal blooms), nutrient cycling, water quality, and food web dynamics.

Environmental Application: Phytoplankton community composition can serve as an early warning signal of toxic or hypoxia-generating algal blooms. If phytoplankton community composition changes in response to hydrological variability, including increased nutrient loads, changes in hydrologic characteristics, and climatic disturbances such as hurricanes and droughts, it can serve as an indicator of estuarine and coastal ecological condition and health because phytoplankton plays a major role in primary production, eutrophication (including harmful algal blooms), nutrient cycling, water quality, and food web dynamics.

Phytoplankton photopigments are used to determine phytoplankton pigments (e.g., chlorophyll) in estuaries and coastal waters. For example, in the Chesapeake Bay, light-based methods of measuring chlorophyll are applied to measure stress. The ground-based PAM fluorescence technique is based on the fluorescence induction of photosynthesis, which is a measure of the efficiency of energy transfer and is applied to measure stress. The remotely-sensed measurements detect different forms of xanthophyll pigments. Xanthophyll pigments change form in order to protect the plant’s photosynthetic system so they can be used as an indicator of stress.

Environmental Application: These indicators can be used as a cost-effective alternative for assessing risk for wetland loss, as well as for monitoring the condition of coastal wetlands and the success of restoration efforts. Resource managers can use this information, for example, to apply mitigation techniques for adjusting sediment supply for wetlands at high risk of inundation.

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ECOSYSTEM STATE

BSS respond to natural or human-induced stressors and can be aggregated into size categories. BSS models can be used in a comprehensive coastal monitoring program on organism abundances must be monitored to indicate changes in the biological community structure, productivity, food-chain efficiency, predator-prey relationships, and effects of environmental variability, fishing, nutrient loading, and habitat change. BSS of stressed ecosystems often have steep negative slopes. For example, in heavily fished ecosystems larger fish may be reduced in number and biomass. On, in highly eutrophic ecosystems with excess nutrient loading, blooms of microscopic phytoplankton can greatly increase the abundance and biomass of small organisms, leading to stressed conditions such as hypoxia and mortality of larger organisms (e.g., crabs, fish).

Environmental Application: BSS can be used by managers to describe long-term effects of stress on the success of restoration efforts in estuaries impacted by human activities. BSS can be applied to a broad suite of aquatic biological communities, not only to selected organisms, and thus can indicate how whole ecosystems are responding to either detrimental conditions or restoration efforts in resource management (e.g., fisheries management, habitat restoration, improved water quality). Periodic monitoring of sizes and abundances of organisms is required to apply BSS as an indicator.

A biomass size spectrum (BSS) depicts the abundance and distribution of organisms by size classes in an ecosystem. In aquatic ecosystems, the biomass (i.e., aggregate weight) of organisms at each level in the food chain from microscopic phytoplankton to the largest vertebrate animals is nearly equal. Because biomass is near equal, numbers of small organisms greatly exceed numbers of large organisms. Size-specific predation (the large organisms eat smaller ones) in aquatic communities maintains the observed biomass size structure and has led to methods for evaluation of size-structure characteristics to relate changes and state of ecosystems. To derive BSS, data from monitoring programs on organism abundances must be analyzed, and biomass of small organisms, leading to stressful conditions such as hypoxia and mortality of larger organisms (e.g., crabs, fish).

**EPA’s Science to Achieve Results (STAR) Estuarine and Great Lakes (EaGLE) Program**

**New Indicators of Coastal Ecosystem Condition**

**Introduction**
Coastal ecosystems, from large extratropical systems to small marshes, are recognized for their important ecological function and societal value, providing food, habitat, and nursery grounds for commercially- and recreationally-important fish and shellfish. Marshes absorb energy from storms and protect the land from hurricanes. These important ecosystems are threatened by multiple human stressors as well as natural disturbances. The nation is losing much of its coastal marsh due to development, land subsidence, erosion, and sea level rise. In some areas, marshes have displaced native plant species, threatening commercially important biological resources by altering habitat and productivity of the marsh. Reduction of water clarity, through increases in suspended sediments and algal blooms, adversely affects the growth of subtidal aquatic vegetation, the nursery grounds for many fish and shellfish. In order to mitigate continued degradation and loss of coastal ecosystem services and to plan for their remediation, new indicators are needed that will predict when and where ecosystem degradation and wetland losses will occur.

Three ecological indicators of coastal condition are being investigated by researchers with the Atlantic Coastal Environmental Indicators Consortium (ACE INC). ACE INC, with funding from EPA’s Science to Achieve Results (STAR) Environmental Protection Agency (EPA’s EaGLe program, www.epa.gov/ncer/centers/eagles) are developing new indicators of coastal ecosystem condition.

**1) PHYTOPLANKTON COMMUNITY**

**Composition as an Indicator of Coastal Ecosystem Condition**

Phytoplankton community composition is a gauge of ecological condition and change. Phytoplankton are suspended microscopic algae. They are the major primary producers in estuarine ecosystems, have fast growth rates, and are sensitive to environmental disturbances. Phytoplankton communities, such as diatoms, dinoflagellates, chrysophytes, cryptomonads, and carotenoids, are molecules that capture and store energy from light. They are the major primary producers in coastal ecosystems. This Atlantic Coast Environmental Indicators Consortium (www.acenic.org) is investigating the overall structure and composition of phytoplankton (1) PHYTOPLANKTON COMMUNITY as an indicator of coastal ecosystem condition.
A biomass size spectrum (BSS) depicts the abundance and distribution of organisms by size classes in an ecosystem. In aquatic ecosystems, the biomass (i.e., aggregate weight) of organisms at each level in the food chain from microscale phytoplankton to the largest vertebrate animals is nearly equal. Because biomass is near equal, numbers of small organisms greatly exceed numbers of large organisms. Size-specific predation (the larger organisms eat smaller ones) in aquatic communities maintains the observed biomass size structure and has led to methods for evaluation of biomass size relationships to characterize the structure and state of ecosystems. To derive BSS, data from monitoring programs on organism abundance must be aggregated into size categories. BSS models can apply BSS as an indicator.

As a result, the slope of the disturbed biomass size spectrum becomes steeper and other statistical properties (e.g., levels of aggregation) may shift. BSS can be used by managers to describe long-term effects of stress or the success of restoration efforts in estuaries impacted by human activities.

**Ecological Indicators:** Changes in the slope or other statistical properties of the normalized BSS relative to reference standards or historical benchmarks is an indicator of changes in the abundance and biomass of suites of organisms in an aquatic ecosystem.

**Ecological Effect/Impact:** Changes in the slope of the normalized BSS can be indicative of changes in the biological community structure, productivity, food-chain efficiency, prey-predator relationships, and effects of environmental variability, fishing, nutrient loading, and habitat change. BSS of stressed ecosystems often have steep negative slopes. For example, in heavily fished ecosystems larger fish may be reduced in number and biomass. On, in highly eutrophic ecosystems with excess nutrient loading, blooms of microscale phytoplankton can greatly increase the abundance and biomass of small organisms, leading to stressful conditions such as hypoxia and anoxia.

**Ecological Effect/Impact:** Direct and indirect effects of human activities have taken a toll on the nation’s estuaries, and for direct linkages have been identified between human activities and land use and responses in estuarine ecosystems. The Atlantic Coastal Estuaries Health Estuarine Consortium (www.acinc.org) is one of five national projects funded by EPA’s EaGLe program. The goal of the EaGLe program is to develop the next generation of ecological indicators that can be used in a comprehensive coastal monitoring program.

**Ecological Indicator:** The structure of phytoplankton communities is a broadly applicable, integrative indicator of ecological condition of aquatic ecosystems.