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 easily quantified. 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 serve as ecological indicators because properties of BSS respond to natural or human-induced stressors. ACE INC scientists at the University of Maryland and New England Aquarium are evaluating BSS as an indicator of ecosystem state in Chesapeake Bay.

**Ecological Indicator:** 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, predation-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. In highly eutrophic ecosystems with excess nutrient loading, biomass of microscopic phytoplankton can greatly increase and shift to a higher trophic level, while numbers of small, undesirable phytoplankton may increase while other statistical properties (e.g., levels of productivity) remain relatively constant.

**Environmental Application:** BSS can be used by managers to describe long-term effects of stress on the success of restoration efforts in estuarine ecosystems 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 deteriorating conditions or remediation efforts in resource management, habitat restoration, improved water quality. Periodic monitoring of sizes and abundances of organisms is required to apply BSS as an indicator.
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, estuarine productivity (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. 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. For example, 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 pigment analyses to determine the dominant phytoplankton species and to assess the health and productivity of coastal waters. These changes can be correlated to increased nutrient loads, shifts in temperature, or changes in water chemistry.

Physiological Indicator: The level of stress of marsh vegetation is an important indicator of marsh productivity and health. Two complementary measurements, one ground-based and the other remotely-sensed, are applied to measure stress. The ground-based technique is based on the primary productivity of marsh vegetation, which in turn is dependent upon the success of the plant life, the amount of sunlight absorbed by the plants, and the efficiency of energy conversion. The remotely-sensed technique utilizes the reflectance of plant pigments, is governed by nutrient and water availability, phytotoxins, salinity, and relative sea level. Combining these measurements with marsh elevation data with measurements of the level of stress of vegetation is an important indicator of marsh productivity, health, and stability.

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.
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In the September 1998 issue of Environmental Management, researchers at the University of North Carolina at Chapel Hill’s Institute of Marine Sciences are using diagnostic photopigments to detect different forms of xanthophyll pigments. A key reason is that these pigments appear to be unique to cyanobacteria (green algae) and chlorophytes (red algae) and that they can provide a key data source for verifying the presence of these pigments in the environment.

The frequency distribution is then compared to marsh elevation data with measurements of the level of stress of vegetation is an integrative indicator of marsh productivity, health, and stability. Two environmental application: These indicators can 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.

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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 in environmental stressors, including increased nutrient loads, changes in hydrologic 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 pigment (e.g., chlorophyll a) concentrations as the criteria for estimating phytodetritus load and temporal (daily to annual, or even longer-term) nutrient load (TMDLs). In addition, diagnostic pigments are used to determine phytoplankton community changes in response to hydrological events such as hurricanes and droughts. Results from North Carolina’s Nuese River Estuary (PMic) Sound system show that when conditions "favor" a transition from hurricanes and flooding to fast growing, low salinity-adapted chlorophytes (green algae) become dominant (Fig. 2). Conversely, when drought conditions prevail, slower-growing dinoflagellates (green algae) become dominant (Fig. 2). In addition, when drought conditions prevail, slow-growing diatoms (green algae) prevail again in estuaries with saltwater inundation (Fig. 2).

 Phytoplankton is an important component of the food web, and the frequency and intensity of phytoplankton blooms are influenced by local and regional hydrological, climatic, and oceanographic factors. Phytoplankton blooms are often associated with the convergence of nutrient-rich waters from different sources, such as rivers, estuaries, and upwelling areas, and with changes in temperature, light, and nutrient availability. The frequency, duration, and intensity of phytoplankton blooms can vary significantly from year to year and can be influenced by a variety of factors, including climate change, ocean warming, and human activities such as nutrient loading from agricultural and sewage sources.

Contribution of some key phytoplankton taxonomic groups (chlorophytes, cyanobacteria, and dinoflagellates) to total chlorophyll a concentrations 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.

Geomorphic Indicator: The vertical elevation relative to mean sea level is an important geomorphic indicator of marsh productivity and stability and is determined by using Light Detection and Ranging (LIDAR) remote sensing. This LIDAR elevation data is combined with a high resolution Airborne Data Collection and Acquisition (ADAC) digital camera image of the marsh landscape to construct a frequency distribution of marsh landcover with elevations relative to the mean sea level. The frequency distribution is then compared to optimal distributions across the range of tolerance for the specific vegetation.

Eccological Effect/Impact: The height of coastal marshes relative to sea level will move upwards or downwards toward equilibrium with the sea depending on the rate of sea level rise and amount of sedimentation. When this equilibrium is reached, the marsh will maintain a stable height relative to sea level. This equilibrium height will decline. A decline in relative elevation of coastal marshes below an optimum level can result in increased risk of inundation.
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Changes in the slope of the normalized BSS can be indicative of habitat change, 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 or the success of restoration efforts in ecosystems 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 aquatic ecosystems are responding to either deterioration or remediation efforts in resource management, habitat restoration, improved water quality. Periodic monitoring of sizes and abundances of organisms is required to apply BSS as an indicator.

Figure 5. Conceptual illustration of a normalized biomass size spectrum. Relative abundances of organisms grouped against weight classes is as an unbroken (left panel), and fragmented right panel. A, unstable (fragmented) abundance and state of organisms (left) may decline (B). As a result, the slope of the biomass size spectrum (BSS) and other statistical properties (e.g., levels of diversity) may shift. Illustration courtesy of William J. Connelly.

Introduction: Coastal ecosystems, from large estuarine systems to salt marshes, are recognized for their important ecological function and societal value. They provide 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, decreasing BSS 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 submerged aquatic vegetation, the nursery grounds for many fish and shellfish. In its early phases, 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 Coast Environmental Indicators Consortium (ACE-INC), which will develop ecological indicators that can be used to identify the condition of the phytoplankton community. Phytoplankton, such as chlorophyta, cyanobacteria, and cryptomonads each have their own unique diagnostic photopigments that can be used to identify the composition of the phytoplankton community. Photopigments, such as chlorophyll-a, can be used to indicate the health of the phytoplankton community (photopigments composition; 2) salt marsh elevation and plant health, and 3) the size distribution of aquatic organisms (Homsa spectroscopy).
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 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 abundances must be aggregated into size categories. BSS models 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 deteriorating conditions or remediation efforts in estuaries impacted by human activities. BSS can be used to manage by describing the long-term effects of stress or 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 deteriorating conditions or remediation efforts in estuaries impacted by human activities. BSS can be used to manage by describing the long-term effects of stress or the success of restoration efforts in estuaries impacted by human activities.

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