Eutrophication, Habitat Dynamics and Trophic Feedbacks: Understanding and Managing Coastal Ecosystems

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As a consequence of natural hydrologic, meteorological and oceanographic processes, ecosystems at the land-sea interface tend to be focal points for delivery of water, sediments, nutrients, and organic matter derived from adjacent environments. This natural fertilization provides the life-blood which makes estuaries and other coastal ecosystems among the world's most highly productive biomes. Inputs of these materials from watershed, atmosphere and ocean to coastal environments vary significantly across a wide spectrum of scales (days-to-decades), with fundamentally different variance spectra depending on the source. Coastal ecosystems and associated populations are highly responsive to these variable inputs and forces. Most organisms in coastal ecosystems are well adapted to the ever-changing habitat conditions resulting from fluctuating inputs. Because of the widely differing characteristic scales of variability for organisms along estuarine food-chains, trophic structures act to filter and propagate input variance. There is much to be learned about the fundamental structure and function of coastal ecosystems by analyzing covariances (amplitude, mode, coherence) in the spectra of temporal and spatial fluctuations among ecological properties and input forces. Overlain on the background variations of nutrient inputs to estuaries are global-scale eutrophication trends of increasing fertilization. Many ecological effects of eutrophication have been well documented, including habitat losses associated with oxygen depletion from deep bottom-waters and declining populations of seagrasses in littoral areas. Because nutrient inputs and cycles are essential to the functioning of coastal ecosystems, responses to over-fertilization often involve complex non-linear interactions, which are not well understood. Ecological feedbacks transmitted along trophic webs and biogeochemical cycles can produce unexpected responses to increases and decreases in nutrient loading to estuaries. Here, we describe regional seasonal and interannual patterns of variability of material inputs and ecosystem properties for Chesapeake Bay, a large estuarine ecosystem on the Atlantic coast of North America. We illustrate how simple mass-balance computations, statistical analyses and numerical simulations provide heuristic insights into mechanism controlling ecosystem dynamics as well as sound management actions for conserving living resources of ecosystems at the land-sea interface.