Summer algal blooms in shallow estuaries: Definition, mechanisms, and link to eutrophication

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Limnol. Oceanogr., 52(1), 2007, 370-384 | DOI: 10.4319/lo.2007.52.1.0370

ABSTRACT: We propose a definition for identification of blooms and use this definition to investigate the underlying mechanisms of summer blooms and their link to nutrient enrichment. Blooms were defined as chlorophyll a observations deviating significantly from a normal seasonal cycle; the frequency and magnitude of these deviating observations characterized bloom frequency and intensity. The definition was applied to a large monitoring data set from five estuaries in Denmark with at least biweekly sampling. Four mechanisms with links to nutrient enrichment were identified as sources of summer blooms: (1) advection from biomass-rich inner estuary, (2) resuspension of nutrients and algae from sediments, (3) nutrient releases from sediments during hypoxic conditions, and (4) decoupling of benthic grazers. Summer blooms were mostly dominated by diatoms, and in 33% of the bloom samples the dominating species was also dominant prior to the bloom. Only four species (*Cerataulina pelagica*, *Chaetoceros socialis/radians*, *Prorocentrum micans*, and *Prorocentrum minimum*) typically (>50% of blooms) increased their biomass proportion during bloom initiations. Bloom frequency and intensity decreased from 1989 to 2004, corresponding to decreases in nutrient inputs and concentrations, but only bloom frequency could be directly linked to the actual total nitrogen concentrations, whereas bloom intensities depended on site-specific features, particularly a threshold response for stations exposed to hypoxia. Bloom frequency has increased over longer timescales in response to nutrient enrichment.

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