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Spatiotemporal patterns of phytoplankton composition and abundance in the Maryland Coastal Bays: The influence of freshwater discharge and anthropogenic activities

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ABSTRACT

The spatial and temporal variations in phytoplankton abundance and community structure in the northern and southern parts of the Maryland Coastal Bays (MCBs) that differ in anthropogenic activities and hydrological characteristics were studied in 2012 and 2013 using photosynthetic pigments as biomarkers. Phytoplankton pigment biomass and diversity were generally higher in the northern bays that receive high nutrient input from St. Martin River, than in the southern bays where nutrient levels were comparatively low. Sites close to the mouths of tributaries in northern and southern bays had higher nutrient levels, which favored the development of dinoflagellates, and nano- and picophytoplankton, than sites closer to the inlets. The microplankton dominated the phytoplankton community in spring (> 90%) and decreased in relative abundance into fall (< 60%) whereas nanoplankton peaked in summer or fall. Picoplankton relative abundance increased from late spring (< 10%, March 2012 & 2013) to summer (40%, July 2012 and August 2013) and was correlated positively with NH_4^+ and negatively with salinity. The observed spatial and seasonal patterns of phytoplankton relative abundance and diversity are likely due to changes in nutrient concentrations and ratios, driven by variations in freshwater discharge, and selective grazing of phytoplankton. Water quality management in the MCBs should continue to focus on reducing nutrient inputs into the bays.

1. Introduction

Phytoplankton play a key role in aquatic ecosystems, hence understanding the structure, dynamics and composition of phytoplankton is essential in ecological studies and environmental monitoring programs (Henriksen et al., 2002; Rodrigues et al., 2014). Changes in phytoplankton community structure may occur in response to environmental variables (e.g. light, nutrients, temperature, and salinity) and/or upper trophic level changes, micro-versus mesozooplankton grazing (Miller et al., 1995; Glibert, 1998; Lewitus et al., 1999; Noble et al., 2003). In coastal oceans, changes in nutrients and water quality due to temporal variations in precipitation and freshwater discharge, coupled with anthropogenic activities can cause changes in phytoplankton species composition, and lead to increases in the occurrence and severity of harmful phytoplankton blooms (Glibert and Burkholder, 2006; Zhu et al., 2010; Gobler and Sunda, 2012).

Coastal lagoons are characterized by shallow water depth, limited exchange with the adjacent oceans, and high primary productivity (Lankford, 1977; Boynton et al., 1996). Photosynthesis in surface water is often augmented by production from macroalgae and seagrasses (Lee and Olsen, 1985). Although they are well-mixed, hypoxia has been reported in some localized areas (Maryland DNR, 2002; Hall and Wazniak, 2005).

In the Maryland Coastal Bays (MCBs), very few studies have addressed the ecology of phytoplankton (Boynton et al., 1996), and have focused on the occurrence of brown tide (*Aureococcus anophagefferens*), the factors influencing its abundance (Glibert et al., 2001; Trice at al. 2004; Deonarine et al., 2006; Minor et al., 2006; Glibert et al., 2007), and its impacts on hard clams, *Mercenaria mercenaria* (Wazniak et al., 2007). The occurrence of other potentially harmful algae species in the MCBs has also been documented (Tango et al., 2004). Glibert et al. (2014) described the eutrophication process in the MCBs and the associated seasonal, spatial and inter-annual variations in four major phytoplankton groups, based on their photosynthetic biomarker pigments. Specifically, they reported increasing trends in the concentrations of zeaxanthin (cyanobacteria), peridinin (dinoflagellates), and fucoxanthin (diatoms), and the fact that NH_4^+ or DON dominated the nitrogen in the water column causing a shift in the phytoplankton community towards picoplankton. Additionally, using freshwater discharge data from Nassawango Creek, which is part of the Chesapeake

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Bay watershed, as a proxy for groundwater flow into the MCBs, they hypothesized that a "change from long-term dry to wet conditions in 2001–2013 altered nutrient loads and internal sediment nutrient cycling" in the Bays. Nevertheless, most of these studies were conducted only in the southern part of the MCBs consisting of Chincoteague, Sinepuxent and Newport Bays, and did not examine the influence of changes in freshwater discharge directly into the bays. Thus, little is known about phytoplankton community composition, diversity and dynamics in the northern bays of Assawoman and Isle of Wight, and the influence of changes in freshwater inflow from St. Martin River, which flows directly into the MCBs, on nutrient and phytoplankton community dynamics. Information on the dynamics of phytoplankton community in both northern and southern bays is needed to gain a better understanding of the responses of phytoplankton community in the whole MCBs system to long and short term changes in water quality and climatic factors.

In this study, the concentrations of eleven diagnostic algal pigments were monitored to evaluate the spatial and temporal changes in phytoplankton community composition over a two year period. The hypothesis that the dynamics in phytoplankton composition, abundance and diversity are due in a large part to variation in freshwater inflow that influences nutrient concentrations in the MCBs is examined. Our objectives are: 1) to examine spatial and seasonal patterns in phytoplankton abundance and diversity, and 2) to determine the main environmental factors influencing phytoplankton abundance, and diversity.

2. Materials and methods

2.1. Study area

The Maryland Coastal Bays (MCBs) are located on the East Coast of the United States and separated from the Atlantic Ocean by the Assateague Barrier Islands (Fig. 1). The bays are shallow (average depth < 3 m), allowing for a vertically well-mixed water column, while circulation is controlled primarily by winds and tides (Kang et al., 2017). Most parts of the bays are euhaline (salinity ranges from 30 to 35) but salinity could be as low as 20 in the Newport Bay and St. Martin River tributaries. Freshwater inputs to the bays are mainly from the Newport Bay and St. Martin River tributaries, though a considerable portion from groundwater (Dillow and Greene, 1999; Wazniak et al., 2007. Land use is mainly forested or agricultural in the south and urban or residential in the north (Wazniak et al., 2007; Duan et al., 2015). The Ocean City Inlet divides the bays into the northern and southern parts, and serves as one of the two points of exchange between the bays and the Atlantic Ocean, the other being the Chincoteague Inlet. Sites 1–5 are located in Chincoteague Bay, site 6 is in Newport Bay, near the mouth of Trappe Creek, and sites 7 and 8 are in the central Sinepuxent Bay. These three bays make up the southern bays. The northern bays consist of Isle of Wight (site 9), St. Martin River (site 10, near the river mouth) and Assawoman Bay (sites 11–13).

2.2. Sample collection and processing

Water samples were collected from 13 sites (Fig. 1) from February 2012 to December 2013 monthly. A peristaltic pump or Van Dorn sampling bottle was used to collect subsurface water at a depth of 0.5 m, stored in 2 L acid cleaned polyethylene amber bottles and preserved in ice before being transported to the laboratory. In low light conditions, samples were filtered through a Whatman GF/F 47 mm filter (for 1–4 mins) using a vacuum pump at pressure below 20 psi. Photosynthetic pigments were immediately extracted with 5 mL of acetone overnight at 4 °C in darkness following sonication for 30s (Zapata et al., 2000) or filters stored at −80 °C for extraction at a later date (< 2 weeks). The extracts were centrifuged using an Eppendorf Centrifuge (model 5415 R) at 2500 rpm for 5 min, filtered (Millipore membrane filters, 0.2 µm nominal pore size), and dried under gentle pressure using a nitrogen evaporator. The residue was re-dissolved in 200 µL of cold methanol before injection in the HPLC.

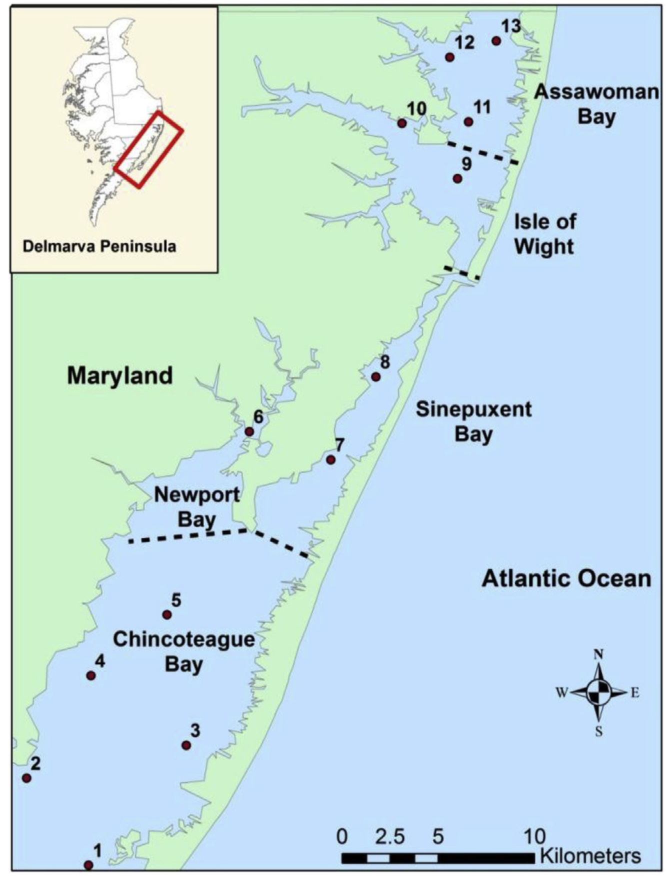

Fig. 1. Map of the Maryland Coastal Bays showing sites where samples were collected for pigment and nutrient analyses. The southern bays are made up of Sinepuxent, Newport and Chincoteague Bays, while Isle of Wight and Assawoman Bays constitute the northern bays. The Ocean City Inlet is located between sites 8 in the south and 9 in the north.

2.3. Analyses of environmental variables

Physicochemical parameters (temperature, salinity and pH) were measured *in situ* at each site using a YSI 6600 multiparameter meter (Yellow Springs, Ohio, USA). Analyses of ammonia (NH_4^+), dissolved silica (DSi), and total dissolved phosphorus (TDP) in filtered water samples were conducted on a HACH DR/4000 UV/VIS Spectrophotometer within 24 h of collection. Dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) were analyzed using a Shimadzu Total Organic Carbon Analyzer (TOC-V-CPH-CPN).

2.4. HPLC pigment analysis

Analysis of pigments, which have been used as biomarkers for the various algal groups to identify changes in phytoplankton community composition, was conducted on an Agilent 1100 Series HPLC following method described in Zapata et al. (2000) with slight modifications. The two eluents used were: (A) methanol:acetonitrile: 0.25 M aqueous pyridine (50:25:25, v/v/v), and (B) acetonitrile: acetone 80:20 (v/v). All organic solvents were HPLC grade and eluents were prepared as described in Zapata et al. (2000). The aqueous pyridine solution was prepared by adding 10 mL of acetic acid and 20 mL of pyridine (Merck) to 900 mL of deionized water in 1 L flask. The pH of the mixture was adjusted to 5 by adding additional acetic acid dropwise. Analytical