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Dynamics of dissolved organic carbon and total dissolved nitrogen in Maryland's coastal bays

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ABSTRACT

Dissolved organic matter (DOM) provides nutrients and energy subsidies for harmful algal blooms in Maryland's Coastal Bays (MCBs, USA). The composition, sources and dynamics of DOM in MCBs are not well known. In this study, dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) were monitored monthly over a period of one year (July 2011 to June 2012) at 13 stations in the MCBs. Absorption and fluorescence spectroscopy were used to characterize DOM composition and track terrestrial inputs *versus* aquatic sources of DOM. Results show that DOC and TDN concentrations in the MCBs (187–501 μM and 19.4–40.6 μM) were comparable to eutrophic coastal waters in the United States but much higher than the mid-Atlantic Bight. This suggests that the MCBs are a DOM source for the coastal ocean. Spatially, nearshore sites had relatively higher DOC and TDN concentrations and terrestrially-derived aromatic DOM (indicated by high humification index) than the bays that were directly connected to the Atlantic Ocean. Seasonally, DOC from the main body of the MCBs (Chincoteague and Assawoman Bays) displayed a pronounced seasonal pattern with the highest values occurring in summer. Protein-like DOM from algal/bacterial inputs (indicated by high biological freshness index or fluorescence index) was also highest in summer but then decreased gradually until April. DOC concentrations at the nearshore site were highest in later spring, probably due to terrestrial inputs. Conversely, TDN concentrations in smaller bays with faster flushing rates (Newport, Sinepuxent and Isle of Wight Bays) were highest in April, probably due to watershed nitrogen inputs. This spring TDN peak was not apparent in the main body of the MCBs, which have longer flushing times (indicating stronger biological nitrogen uptake). This study suggests that DOM in eutrophic, shallow coastal bays such as the MCBs consists of a large fraction of protein-like components from local algal/microbial sources during summer. This enhanced primary productivity is likely fueled by watershed nitrogen inputs from agricultural and urban land use during spring. Further insights regarding spatiotemporal variations and controls of DOM abundance, composition and sources in the MCBs can be helpful in guiding and prioritizing coastal restoration efforts for reducing eutrophication and water quality degradation.

1. Introduction

Eutrophication is a widespread problem in the United States, particularly in coastal lagoons of the mid-Atlantic U.S. (Bricker et al., 2008). Relative to classical river-dominated systems, coastal lagoons are shallow and demonstrate strong benthic–pelagic coupling. They have minimal freshwater input as well as limited oceanic exchange (Kurtz et al., 2006; Madden, 2010; Glibert et al., 2010). The Maryland's Coastal Bays (MCBs) or lagoons extend the full length of the state's Atlantic coast, and provide habitat for a variety of wildlife (Schwartz, 1964; Casey and Wesche, 2001). However, water quality in the MCBs has been declining over the past few decades coinciding with watershed urbanization and animal operations (Nosakhare et al., 2012), as evidenced by increases

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in nutrient loads (Boynton et al., 1996) and outbreaks of brown tides (Goshorn et al., 2004; Trice et al., 2004; Glibert et al., 2001, 2007, 2014). The degradation of water quality in the MCBs has affected living resources such as seagrass coverage (Wazniak et al., 2007; Orth et al., 2006), and the abundance and species richness of fishes (Murphy and Secor, 2006; Pincin et al., 2014).

Recent studies have shown that water quality in the MCBs impacts the abundance, composition and sources of dissolved organic matter (DOM). Occurrence of harmful algal blooms (HABs) in the MCBs has been intimately associated with an increase in watershed transport of organic nutrients (Glibert et al., 2007). For example, dissolved organic nitrogen urea has been considered to be a potential cause for outbreaks of brown tides (Glibert et al., 2001; Wazniak and Glibert, 2004). However, a large amount of DOM can also be released shortly after algal blooms (Simjouw et al., 2004; Minor et al., 2006), which can remain in the system or be exported to the Mid-Atlantic Bight (Minor et al., 2006). DOM at two nearshore sites of Chincoteague Bay (the largest MCB) were measured and characterized in previous research based on molecular weight, light absorbance, and stable isotope composition (Simjouw et al., 2004; Minor et al., 2006). Results showed that algal-derived DOM was high in molecular weight, aromatic in nature, and nitrogen enriched (Simjouw et al., 2004; Minor et al., 2006). As expected, the abundance, composition and sources of DOM varied seasonally and annually with changes in chlorophyll-*a* (chl-*a*) concentrations (Minor et al., 2006). However, we are not aware any study addressing DOM dynamics at other sites of the MCBs.

Our primary objective in this study was to examine the dynamics of DOM throughout the whole area of the MCBs. Our research questions were: 1) how do concentrations, composition and sources of DOM vary spatially in the MCBs, 2) how do concentrations, composition and sources of DOM vary seasonally and 3) what are the possible factors controlling the DOM dynamics in the MCBs? We monitored dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) from July 2011 to June 2012 at 13 sites throughout the MCBs system. The composition and sources of DOM were examined with UV/Visible light absorbance, fluorescence spectroscopy, and chlorophyll-*α*. This study can be helpful in guiding and prioritizing coastal restoration efforts for reducing eutrophication and water quality degradation.

2. Materials and methods

2.1. Study sites

Background information regarding site descriptions of the MCBs is available in many previous studies (Quinn et al., 1989; Lung, 1994; Boynton et al., 1996; Allen et al., 2007; Fertig et al., 2013; Pincin et al., 2014). Briefly, the MCBs system consists of a series of shallow (<3 m), well-mixed lagoons/bays between the east side of the Delmarva Peninsula on the East Coast of the USA and two barrier islands (Fig. 1). The MCBs can be divided into two regions (north and south bays) using the Ocean City inlet to the Atlantic Ocean as a boundary. The north bays, including Assawoman and Isle of Wight Bays, are located behind the Fenwick barrier island. Average salinities range between 27 and 31 (Pincin et al., 2014), while flushing rates vary from 9.45 days in Isle of Wight Bay, 12 days in St. Martin River, to 21.2 days in Assawoman Bay (Pritchard, 1960; Lung, 1994). The south bays, comprising Sinepuxent, Chincoteague, and Newport Bays, are located behind the barrier island, Assateague. Salinities range from near 0 at the headwaters of Trappe Creek, which feeds Newport Bay, to 32 in Chincoteague Bay (where evaporation rates exceed freshwater input). The south bays have average depths ranging between 0.67 and 1.22 m (Boynton et al., 1996; Allen et al., 2007) and are more poorly flushed than the north bays (Quinn et al., 1989; Boynton et al., 1996). The flushing rate has been estimated to be up to 63 days (Pritchard, 1960). Tidal range near the Ocean City Inlet is more than 1 m, whereas it is only ~0.12 m in the middle of Chincoteague Bay and ~0.46 m in Assawoman Bay (Boynton et al., 1996).

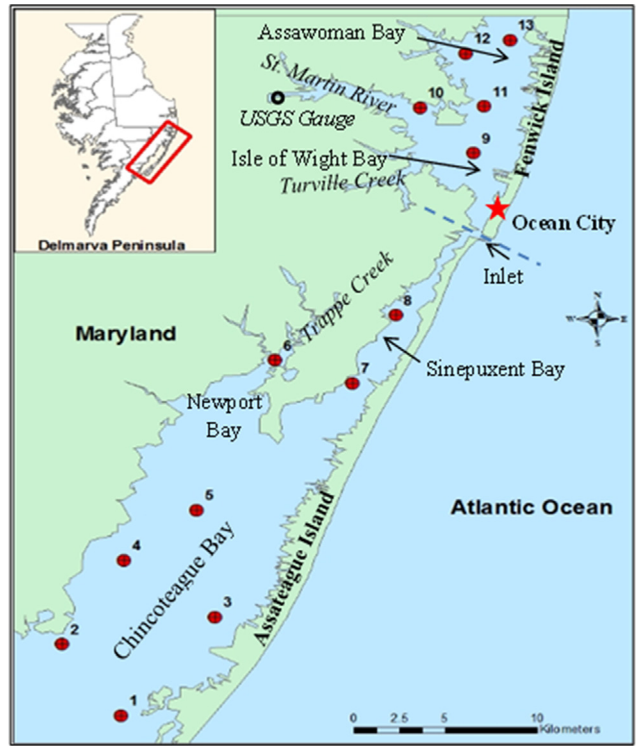

Fig. 1. Map of the Maryland's Coastal Bays (MCBs) and sampling sites (in red dots). MCBs are divided to north bays and south bays using the Ocean City Inlet as a boundary. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The surrounding watershed of the MCBs is relatively small (452 km^2), and land cover is dominated by forests (39.5%) and row crop agriculture (31.8%). Industrial poultry feeding operations (1.1%) are also located within the watersheds. Land use in the northern bays watershed includes more residential and urban development (around Ocean City) than the south bays, and anthropogenic eutrophication from wastewater is more prevalent in the northern region (Murphy and Secor, 2006). Agriculture is relatively more prevalent in the southern region (~33%, primarily corn and soy beans; Wazniak et al., 2007), with high occurrence of septic systems in residential towns (Souza et al., 1993). Human population in the watershed of the MCBs has increased substantially over the past several decades and is expected to double in the coming decades due to urbanization (Wazniak et al., 2007). Moreover, increasing populations of tourists during summer months provide additional impacts to the region.

2.2. Field sampling

Water samples were collected monthly at 13 sites in the MCBs (Fig. 1) over approximately a year from July, 2011 to June, 2012. The north bays and the south bays were sampled at different dates during the first two cruises (Fig. 2) because the sampling and sample processing could not be finished within one day. Samples were not collected for the south bays in September 2011 owing to equipment failure. The information on the sampling sites is