Estuarine, Coastal and Shelf Science xxx (2014) 1–13

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Benthic metabolism and nutrient regeneration in hydrographically different regions on the inner continental shelf of Southern New England

Q1 Lindsey Fields [a,*], Scott W. Nixon [a], Candace Oviatt [a], Robinson W. Fulweiler [b]

[a] University of Rhode Island, Graduate School of Oceanography, South Ferry Road, Narragansett, RI 02882, USA
[b] Boston University, Departments of Earth & Environment and Biology, 685 Commonwealth Ave, Boston, MA 02215, USA

ARTICLE INFO

Article history:
Received 24 October 2013
Accepted 14 June 2014
Available online xxx

Keywords:
benthic metabolism
regeneration
continental shelves
stratification
benthic-pelagic coupling
organic matter

ABSTRACT

We examined the effect of hydrography on benthic-pelagic coupling in a transitional inner continental shelf area. From Oct 2009 to Jul 2012, we measured sediment oxygen demand (SOD), benthic inorganic nutrient fluxes, and sediment characteristics (e.g. chl *a* and phaeopigment content, grain size, etc.) in two regions of the Southern New England continental shelf: a relatively well mixed ecosystem (Block Island Sound, BIS), and an adjacent, seasonally stratified ecosystem (Rhode Island Sound, RIS). Despite a higher rate of euphotic zone primary production in BIS, benthic metabolism (measured as SOD) was not significantly different between the two areas (BIS = 953.8 ± 88.2 μmol m^{-2} h^{-1}; RIS = 912.2 ± 69.1 μmol m^{-2} h^{-1}). We speculate that the similarity of SOD at these two sites was due to differences in water column hydrography between the Sounds, where the energetic water column mixing in BIS could potentially resuspend organic matter back to the water column to be decomposed before reaching the benthos. Additionally, we think that the seasonal presence of a strong pycnocline in RIS prevented mixing of regenerated DIN and DIP to surface waters for use by phytoplankton. Apparent differences in benthic macrofaunal abundance between Block Island Sound and Rhode Island Sound translated to differences in dissolved inorganic nutrient fluxes between the two areas. Excretion and irrigation activities by the dense amphipod communities in BIS likely caused higher effluxes of DIN (NH_4^+ = 36.9 ± 7.7 μmol m^{-2} h^{-1}; NO_X = 23.5 ± 3.4 μmol m^{-2} h^{-1}) and DIP (7.2 ± 1.4 μmol m^{-2} h^{-1}) compared to fluxes in RIS (NH_4^+ = 22.8 ± 4.5 μmol m^{-2} h^{-1}; NO_X = 11.1 ± 5.5 μmol m^{-2} h^{-1}; DIP = 3.2 ± 0.8 μmol m^{-2} h^{-1}). These findings indicate that the hydrographic regime of the water column may exert a strong influence on benthic-pelagic coupling dynamics on the Southern New England shelf and in other inner continental shelf ecosystems.

1. Introduction

Benthic-pelagic coupling, or the link between the benthos and the water column, is a cyclical dynamic in aquatic ecosystems. Water column phenomena affect the benthos, and, in turn, sediment recycling of nutrients and organic matter fuel water column production (Nixon, 1981; Nowicki and Nixon, 1985; Rudnick and Oviatt, 1986; Boynton et al., 1995). Water column organic matter (e.g. phytoplankton, zooplankton feces, etc.) has various fates. It may sink out of surface waters to be buried in the sediment or metabolized by the benthos through uptake of particles by active filtration or direct consumption of deposited material (Hale, 1974; Hopkinson et al., 2001; Woulds et al., 2009). Resuspension of this deposited organic matter by tidal and storm currents may lead to oxidation in the water column. When benthic communities metabolize the energy and nutrients (e.g. carbon, nitrogen, and phosphorus) in this organic matter, they consume oxygen and other terminal electron acceptors, while simultaneously regenerating inorganic nutrients to the water column (Hargrave, 1973; Zeitzschel, 1980; Nixon, 1981; Oviatt et al., 1984). Benthic-pelagic coupling is an important characteristic of coastal systems (Rowe et al., 1975), and many estuarine ecosystems have been well studied, for example Chesapeake Bay (Zeitzschel, 1980; Garber, 1982), the Delmarva Peninsula (Reay et al., 1995), Narragansett Bay (Nixon,

* Corresponding author. Present address: University of Georgia, Department of Marine Sciences, 325 Stanford Drive, Athens, GA 30605, USA.
E-mail addresses: lfields@uga.edu (L. Fields), coviatt@gso.uri.edu (C. Oviatt), rwf@bu.edu (R.W. Fulweiler).

http://dx.doi.org/10.1016/j.ecss.2014.06.007
0272-7714/© 2014 Published by Elsevier Ltd.

1981; Fulweiler and Nixon, 2009), and Alfacs Bay, Spain (Vidal and Morguí, 2000). However, such measurements are relatively less common in continental shelf sediments, and there is still much to be learned about benthic flux dynamics in these transitional ecosystems.

The magnitude and variability of benthic fluxes is driven largely by inputs of organic material from the water column (Hargrave, 1973; Kelly and Nixon, 1984; Hopkinson and Smith, 2005). Hargrave (1973) demonstrated a positive relationship between water column primary production and benthic metabolism (measured as sediment oxygen uptake), and proposed that his findings might reflect a stronger relationship between organic matter supply and benthic community metabolism than that of metabolism and temperature. Just over a decade later, organic matter addition experiments by Kelly and Nixon (1984) found direct evidence of how the quantity of organic matter deposited to the benthos influences sediment fluxes of oxygen and nutrients. Recently, field observations and experimental manipulations in Narragansett Bay found that both the quantity and quality of organic matter were important in driving sediment fluxes (Fulweiler et al., 2007; Fulweiler and Nixon, 2008; Nixon et al., 2009).

Of course, other factors can contribute to benthic flux variability and the relative importance of such factors is debatable and varies across systems (Hopkinson and Smith, 2005). Temperature is known to be an important benthic flux driver and site-specific temporal changes in benthic respiration are strongly related to temperature (e.g. Nixon et al., 1976; Giblin et al., 1997). Additionally, sediment disturbance from animal activity exerts a major influence on benthic flux magnitude and variability (Aller, 1982; Aller et al., 1983). Regardless, Hopkinson and Smith (2005) recently concluded that overall organic matter appears to be the primary driver of benthic metabolism.

There are many phenomena that impact organic matter production and loading, and thus influence the seasonality, magnitude, and variability of oxygen uptake and nutrient recycling at the sediment–water interface. Many studies in both freshwater and coastal marine ecosystems have addressed the effect of water column stratification on either nutrient cycling (e.g. Petihakis et al., 2005; Bruce et al., 2008; Kim et al., 2009) or particle sinking (e.g. Gibbs, 2001), both of which play obvious roles in benthic-pelagic coupling. Though the presence of a pycnocline can decrease the sinking velocity of detritus and other particles (Yamamoto, 1984), resuspension caused by a well-mixed water column or deep mixed layer results in an increase in the amount of organic matter consumed in the water column (Hargrave, 1973). The presence of water column stratification also inhibits mixing of regenerated nutrients up to the surface waters (Cushing, 1989). In coastal marine ecosystems, benthic nutrient remineralization is responsible for a large portion of the nitrogen (N) and phosphorus (P) required by phytoplankton (Rowe et al., 1975; Nixon et al., 1976). However, during times of year when the water column is stratified, primary production in surface waters is supported largely by recycled nitrogen in surface waters instead of remineralization from the benthos (Malone et al., 1988; Cushing, 1989).

The objective of this study was to examine the effect of water column stratification on benthic-pelagic coupling in transitional shelf ecosystems. We directly compared three years of measurements of benthic fluxes (oxygen, ammonium, nitrate + nitrite, phosphate, and dissolved silica) and sediment characteristics (photopigments, C/N ratio, and organic matter content) between two adjacent, phytoplankton-based inner continental shelf ecosystems of similar depth (~30 m) with differing hydrographic regimes. The first ecosystem, Block Island Sound, was relatively more well mixed while the second area, Rhode Island Sound, was seasonally stratified (Fig. 1). We hypothesized that differences in water column stratification between Block Island and Rhode Island Sounds (BIS and RIS, respectively) would lead to differences in organic matter deposition to the benthos and the distribution of recycled nutrients. In turn, we hypothesized that these changes would impact both the magnitude of benthic fluxes and the strength of benthic-pelagic coupling. Specifically, we expected the magnitude of the benthic fluxes to be lower, and thus the link between the water column and the benthos to be weaker in the seasonally stratified system (RIS) compared to the relatively well-mixed system (BIS).

2. Materials and methods

2.1. Study areas

We focused our sampling efforts in two regions on the Southern New England continental shelf, Block Island Sound and Rhode Island Sound, which are adjacent inner shelf ecosystems located off the coast of Rhode Island (Fig. 1). The Sounds are connected to Narragansett Bay, Buzzards Bay, Long Island Sound, Vineyard Sound, and the Atlantic Ocean (Fig. 1). They are both open-water, phytoplankton-based systems with similar mean depths (~30 m), but have contrasting hydrographic regimes. Strong tidal mixing causes a relatively well-mixed water column in Block Island Sound, whereas Rhode Island Sound is vertically stratified during the summer (Shonting and Cook, 1970; Codiga and Ullman, 2011). The thermal stratification in Rhode Island Sound appears to cause summer nutrient limitation, which is likely the cause of lower surface chlorophyll *a* concentrations and primary production in Rhode Island Sound than in Block Island Sound (Table 1; Fields, 2013).

From October 2009 to August 2012 we sampled three stations in fine-grained, depositional areas (Fig. 1). We visited two stations approximately seasonally throughout the entire ~3 year period (one station in Block Island Sound (BIS), and one in Rhode Island Sound (RIS2)), and another station in Rhode Island Sound (RIS1) once per season over one annual cycle (Fig. 1).

2.2. Field collection

On each sampling trip we collected triplicate sediment cores with a 0.25 m^2 box corer containing PVC sub-cores (Hopkinson

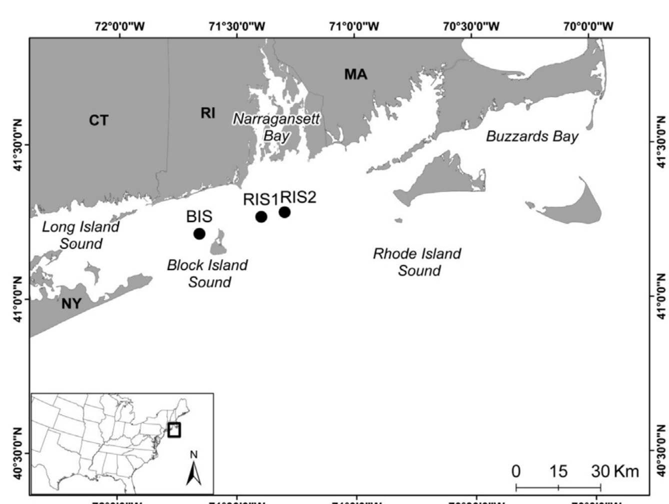

Fig. 1. Map of study sites on the inner Southern New England continental shelf where we measured sediment oxygen demand and inorganic nutrient fluxes across the sediment–water interface to examine how hydrography alters benthic metabolism.