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Spatial and temporal patterns of macroscopic benthic primary producers in Saginaw Bay, Lake Huron

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ABSTRACT

We investigated spatial and temporal patterns in macroscopic benthic primary producer biomass, production, and composition in inner Saginaw Bay in 2009 and 2010. Charophytes and filamentous algae (FA) were relatively abundant, and vascular macrophytes were less common. The probability of benthic primary producer presence increased with the proportion of benthic substrate composed of rock. Most benthic primary producer biomass occurred at depths of 2–4 m, with very little biomass observed beyond 4 m deep. Charophyte and vascular macrophyte abundances displayed consistent patterns related to distance from the mouth of the Saginaw River. FA abundance also displayed such patterns, but they reversed between 2009 and 2010. Macrophytic benthic primary producer communities were generally dominated by charophytes. Three genera of vascular macrophytes, including *Myriophyllum*, were also observed. Filamentous algal communities were composed of a mixture of FA taxa. Ten FA genera were observed, including the red alga *Compsopogon*. Dominance of *Compsopogon* was related to low water clarity and low TP. Biomass-based benthic production estimates indicated that charophytes and FA strongly dominated macroscopic benthic production; production of vascular macrophytes was relatively low. The observed relationships of abundance and environmental conditions suggested regulation of benthic producer biomass by a shifting mosaic of substratum, nutrient, and light availabilities. The diverse nature of the benthic producer community could complicate understanding and management of excess benthic biomass and beach fouling in Saginaw Bay.

Introduction

Saginaw Bay is an ecologically and economically important region within the Laurentian Great Lakes, supporting fisheries, wildlife, recreation, and drinking water withdrawals (e.g., Fahnenstiel et al., 2008; Ivan et al., 2011; Public Sector Consultants, Inc., 2002). The Saginaw Bay ecosystem is subject to a wide variety of environmental stressors, including invasive species, eutrophication, and harmful algal blooms (Fahnenstiel et al., 2008; Public Sector Consultants, Inc., 2002). One of the most notorious of these stressors is the dreissenid mussel. Dreissenids were discovered in the bay in 1991, quickly proliferated, and altered benthic physical structure (Bially and MacIsaac, 2000), community structure, and energy flow (Nalepa and Fahnenstiel, 1995; Nalepa et al., 1995).

Immediately following mussel invasion, macroscopic benthic filamentous algal (FA) biomass (Lowe and Pillsbury, 1995) and macrophyte occurrence frequency (Skubinna et al., 1995) increased in Saginaw Bay. Such responses are common in freshwater systems invaded by dreissenid mussels (Higgins and Vander Zanden, 2010). Additional hard substrate (mussel shells), increased benthic light availability, and P-redistribution from pelagic to benthic habitats (i.e., the "nearshore shunt" of Hecky et al., 2004) have all been suggested as reasons for such "benthification" (sensu Zhu et al., 2006) of coastal Great Lakes ecosystems (Higgins et al., 2008a).

Macroscopic benthic primary producers are important components of most aquatic ecosystems, providing a production base for food webs; habitat and cover for epiphytes, fish, and invertebrates (e.g., Duggan and Francoeur, 2007; Lowe et al., 1982; Van Overdijk et al., 2003); and supporting key steps in biogeochemical cycles (Wetzel, 2001). However, an overabundance of benthic primary producers can contribute to problems such as oxygen depletion, taste/odor in drinking water, and beach fouling (Lembi, 2003). Filamentous algae, charophytes, and vascular macrophytes contribute to beach fouling in the Great Lakes, including Saginaw Bay (Barton et al., 2014; Higgins et al., 2008a; Public Sector Consultants, Inc., 2002, and authors' personal observations), causing esthetic and recreational use impairments and potentially harboring fecal indicator bacteria and pathogens (Byappanahalli et al., 2003; Heuvel et al., 2010; Public Sector Consultants, Inc., 2002).

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The responsiveness of benthic primary producers to many of the stressors in Saginaw Bay (e.g., nutrients, invasive species) and their contributions to environmental and economic problems (e.g., beach fouling) suggest that management of benthic primary producers may be needed. Surveys of benthic producers in Saginaw Bay were conducted in response to the initial dreissenid invasion (Lowe and Pillsbury, 1995; Skubinna et al., 1995), however, these studies were either limited to FA in the outer bay (Lowe and Pillsbury, 1995) or did not consider biomass and production of benthic producers (Skubinna et al., 1995). Of course, both previous studies reflect immediate post-invasion, not present-day, conditions. Thus, little is known about the current distribution, biomass, composition, and regulation of benthic primary producers inhabiting inner Saginaw Bay. Such information is needed to develop sound management strategies and to serve as a baseline for assessing their effectiveness.

In this paper, we quantified spatial and temporal patterns in biomass, community composition, and production of submerged macroscopic benthic primary producers (i.e., vascular macrophytes, charophytes, and macroscopic growths of benthic filamentous algae) in inner Saginaw Bay, and examined how these communities change in relation to potentially-influential environmental factors, including substrata, nutrients, and light.

Methods

Study area

This study took place in the nearshore zone (<10 km off shore) of inner Saginaw Bay, Lake Huron. The inner bay is a eutrophic, well-mixed system with a mean depth of ~5 m and a complex, but generally counterclockwise, weak circulation pattern (mean velocity 7 cm/s) driven by local wind changes (Danek and Saylor, 1977; Nalepa et al., 2002, 2003). The substrate is heterogeneous, with varying coverage of silt/mud, cobble, and rock (Nalepa et al., 1995). The hydraulic flushing time for the inner bay is approximately 140–200 days (Beletsky et al. NOAA/GLERL, in prep) and is highly influenced by flow from the Saginaw River, which makes up about 70% of the total flow into Saginaw Bay (Nalepa et al., 1995). Saginaw Bay is classified as an "Area of Concern" by the International Joint Commission due to excessive eutrophication, degradation of esthetics and the benthos, beach closings, and other runoff-related environmental impacts (Millie et al., 2006; Nalepa and Fahnenstiel, 1995; Nalepa et al., 2002; Public Sector Consultants, Inc., 2002; Selzer, 2008).

Survey design

We quantified benthic primary producer abundance and composition within an oblong region in the southwest portion of the inner bay, approximately 30 km long and 3.5 km wide (105 km^2) extending from 5 km east of the Saginaw River to just north of Pinconning, MI (Fig. 1). Preliminary observations in 2008 and early 2009 confirmed that this region included a zone of abundant benthic FA growth. Within the survey region, 9 transects oriented perpendicular to the shoreline were created to coincide with those established by Skubinna et al.'s (1995) previous survey. The locations and numbering scheme for these transects (transects # 9–18, Fig. 1) reflect that of Skubinna et al. (1995). Individual sites (i.e., depth stations along individual transects) were created along each of the 9 transects at 0.5, 1.0, 2.0, 3.0, and 4.0 m

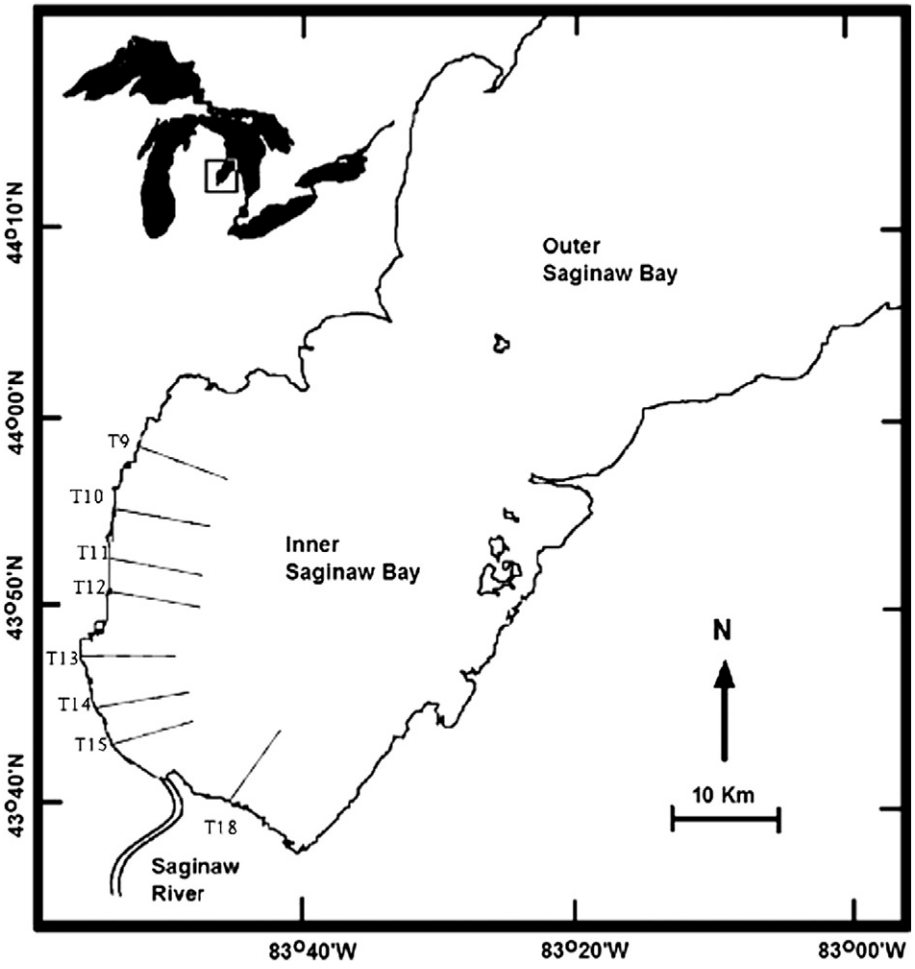

Fig. 1. Study area and sampling transects perpendicular to shoreline.

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