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Commentary

Great Lakes rivermouth ecosystems: Scientific synthesis and management implications

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ABSTRACT

At the interface of the Great Lakes and their tributary rivers lies the rivermouths, a class of aquatic ecosystem where lake and lotic processes mix and distinct features emerge. Many rivermouths are the focal point of both human interaction with the Great Lakes and human impacts to the lakes; many cities, ports, and beaches are located in rivermouth ecosystems, and these human pressures often degrade key ecological functions that rivermouths provide. Despite their ecological uniqueness and apparent economic importance, there has been relatively little research on these ecosystems as a class relative to studies on upstream rivers or the open-lake waters. Here we present a synthesis of current knowledge about ecosystem structure and function in Great Lakes rivermouths based on studies in both Laurentian rivermouths, coastal wetlands, and marine estuarine systems. A conceptual model is presented that establishes a common semantic framework for discussing the characteristic spatial features of rivermouths. This model then is used to conceptually link ecosystem structure and function to ecological services provided by rivermouths. This synthesis helps identify the critical gaps in understanding rivermouth ecology. Specifically, additional information is needed on how rivermouths collectively influence the Great Lakes ecosystem, how human alterations influence rivermouth functions, and how ecosystem services provided by rivermouths can be managed to benefit the surrounding socioeconomic networks.

Introduction

Rivermouth ecosystems occur at the interface between riverine and lentic ecosystems and tend to be a focal area for human development. This is true not only in marine settings (Beaumais and Laroutis, 2007; Elliott and Whitfield, 2011) but also in the Laurentian Great Lakes (Fig. 1), in part because these systems provide a rich array of ecosystem services. Rivermouths are frequently the areas where humans interact with the Great Lakes and are valuable to the economic networks that surround the lakes (Allan et al., 2013; Braden et al., 2008; Taylor et al., 2006). Not surprisingly, this intense human focus on rivermouths has often resulted in substantial alterations to the biophysical structure and function of these systems. For example, a majority of the Great Lakes Areas of Concern (AOCs) are associated with rivermouths (EPA, 2011).

In addition to their value to the economies that surround the Great Lakes, rivermouths appear to have a strong influence on Great Lakes ecosystems themselves. Rivermouths and associated habitats are important for the life cycles of many Great Lakes fish species (Jude and Pappas, 1992), strongly influence nearshore water quality and thermal regimes (Howell et al., 2012), and may be extremely active in the biogeochemical cycling of important elements such as nitrogen (N) and phosphorus (P) (Morrice et al., 2004; Steinman et al., 2009). Further, while many of the open waters of the Great Lakes are becoming less productive due to the effects of invasive species and improved agricultural practices (Evans et al., 2011), biotic production and diversity can be high in rivermouths (Höök et al., 2008; MacKenzie et al., 2004; Minns and Wichert, 2005).

Despite their ecological and economic importance, rivermouths are rarely the focus of system-scale research or management efforts.

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Rivermouths have, in a sense, slipped into a divide between researchers and managers focused on the Great Lakes proper and researchers focused on upstream watersheds. Similarly, coordination among organizations that manage rivermouths has also been limited, with management focused on geographic boundaries rather than on system-scale consideration of lake–landscape interactions. Synthesizing an improved understanding of rivermouths and identifying research needs and management challenges require expertise spanning ecosystem types and scientific disciplines. The information presented here is the product of a diverse group of scientists and managers brought together to: 1) highlight the importance of these ecosystems, 2) integrate current scientific understanding of their structure and function, 3) identify key research needs, and 4) provide guidance towards their effective and sustainable management. Improved understanding of rivermouth function and role in the coastal mosaic should improve the success of current and future efforts to restore and manage Great Lakes nearshore and tributary ecosystems, particularly in the face of land-use change, transforming economies, and changing climate.

Rivermouths: Characteristics, services, and scientific understanding

What is a rivermouth?

Rivermouths are mixing zones that occur at the confluence of lotic and lentic ecosystems, where predictable physical and chemical attributes create spatial gradients and a mosaic of habitats, biotic assemblages, and related ecosystem services. Humans are embedded in these ecosystems and exert influence on, and benefit from, their characteristic properties. Three basic elements interact in every rivermouth: 1) riverine (lotic) inputs of energy (hydraulic and biochemical), water, sediment, and other transported materials; 2) lake-derived inputs of energy, water, sediment, and other materials; and 3) a distinct (and often dynamic) local set of physiographic conditions (in the mixing zone) that reflect both the natural coastal geomorphic setting and the sometimes extensive human alterations to this setting. The unique biophysical structures and processes of each rivermouth are driven by the specific characteristics of each combination of river, lake, and local geography.

Rivermouths themselves can typically be divided longitudinally into three, more or less distinct, zones (Fig. 2): the lower river valley and floodplain, whose lateral extent, complexity, and degree of vertical incision depends on geological history; a semi-enclosed receiving basin or hydrologic storage area (occasionally absent or consisting of only the valley walls themselves); and the nearshore area influenced by the plume of water and associated dissolved and suspended material exiting this storage area. The lower river valley slope is typically low, floodplains are frequently inundated, and backflushing due to strong lake seiches has some influence on river flow and erosional patterns. Backwater and backflushing influences of the Great Lakes may extend long distances upstream, far from the actual lake itself (Bedford, 1992). The receiving basin or hydrologic storage area is where the river channel gives way to a more lentic environment, and depositional rates can be very high. Depending on the local geologic history, the receiving basin can be wide, shallow, and comprised mostly of wetlands, deep and lake-like, or essentially absent, with the river channel discharging directly into the adjacent Great Lake (Fig. 2). Finally, the bathymetry, mouth morphology, and nearshore circulation patterns all influence the temporal and spatial extent of the plume-influenced nearshore area. The exiting plume can be wide or narrow, can represent a sharp or diffuse boundary among water masses, and can be directed out into the lake across increasing depth contours or along shore by lake currents and nearshore thermal gradients (Rao and Schwab, 2007). Typically, the three different rivermouth zones are characterized by different dominant hydrological processes: gravity-driven flow in

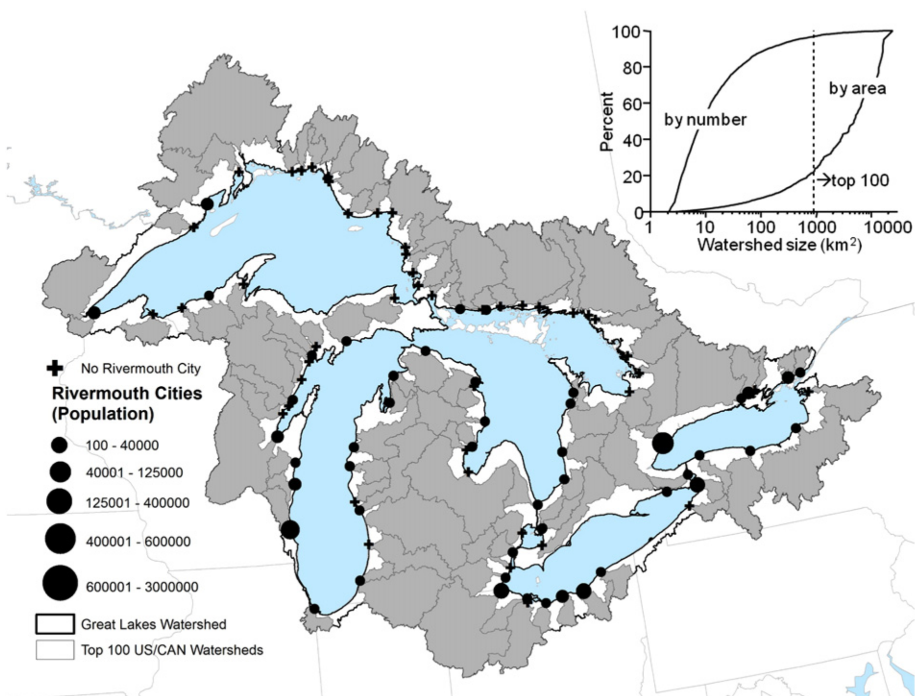

Fig. 1. Map showing the distribution of rivermouths in the Great Lakes and their associated human populations. This linkage enhances both the likelihood for anthropogenic impacts on rivermouths and the likelihood that humans benefit from the ecosystem services rivermouths provide. For visual clarity, only the one hundred largest tributary watersheds (shaded areas) and mouths (circles) are mapped. Most of the almost 3000 Great Lakes tributaries have much smaller watersheds, but the 100 largest cumulatively comprise >75% of the overall basin area (inset cumulative distribution plot).