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From the Great Lakes flows a Great River: overview of the St. Lawrence River ecology supplement

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Introduction

The articles gathered together in this special issue of *Hydrobiologia* stem from a two year conference series (2008 & 2009) co-hosted by the St. Lawrence River Institute of Environmental Science at Cornwall, ON and the Great Rivers Center at Clarkson University, of Potsdam, NY.[1] The conference commemorated what have been arguably the most significant ecological impacts on this river since the Wisconsin Glacial Episode, namely, the damming of the St. Lawrence River to create an hydroelectric power dam and the concomitant creation of the St. Lawrence Seaway lock system that allowed ocean-going vessels to enter the furthest reaches of the Laurentian Great Lakes. Studies on the St. Lawrence River ecosystem in the past have varied in scope and generally focused on the river reaches downstream from the power dam at Cornwall, ON and Massena, NY. In contrast, the International Section of the St. Lawrence River, from the headwaters at Lake Ontario to the entry of the river fully into Canada, has been relatively under-studied (Twiss, 2007).

Notable publications documenting the St. Lawrence River ecosystem are provided by Patch & Busch (1984), the St. Lawrence Centre (1996), a special issue published in the *Canadian Journal of Fisheries and Aquatic Science* (Lean, 2000, and references cited therein), an analysis by Vincent & Dodson (1999), and a recent report by Talbot (2006). We count this special issue among these milestones as a contribution to our understanding of the ecological functioning of a large river that, like most large rivers globally, is under marked ecological stress from a variety of sources,

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[1] For the sake of brevity, the articles published in this special issue of *Hydrobiologia* do not appear in the bibliography of this text.

some of which are detailed in this collection of manuscripts and are summarized below.

Plankton and benthic organisms

Farrell et al. (this issue) have compiled an intriguing data set with temporal end members that bracket significant manipulations to the St. Lawrence River ecosystem: the purposeful setting and enforcement of nutrient abatement technologies by the Great Lakes Water Quality Agreement (1978; International Joint Commission, 1994), and the unintentional invasion of the Laurentian Great Lakes–St. Lawrence River system by dreissenid mussels in the late 1980s and later by the round goby (*Neogobius melanostomus*). The ecological monitoring that was conducted by Farrell et al. (this issue) in the upper reach (Thousand Island Archipelago) of the International Section of the St. Lawrence River provides valuable insight into the ecological processes that occur as water travels through the archipelago. The article by Twiss et al. (this issue) describes at high spatial resolution the changes in plankton that occur in the International Section of the St. Lawrence River from Lake Ontario through the archipelago to the impoundment created by the power dam. Clear decreases in phytoplankton and zooplankton are documented, and confirm earlier observations and those of Farrell et al. (this issue). The data suggest that grazing due to benthic organisms (mussels, insect larvae, sessile rotifers and protists) are the primary source of phytoplankton loss along this stretch of the St. Lawrence River.

Masson et al. (this issue) examine ecological trends along a long section of the St. Lawrence River from Montréal to Québec City. Through the assessment of macroinvertebrate community structure in relation to chemical and physical parameters, they conclude that sediment contamination is not the primary predictor of assemblages compared to physical and non-contaminant chemical parameters of the habitat.

The complex hydrology of the St Lawrence River includes both lentic and lotic ecosystems with specificities in terms of community dynamic. In the fluvial Lake St. Pierre, Cremona et al. (this issue) report that macroinvertebrate communities form complex food webs with several trophic levels resulting from high variation in habitat and environmental conditions that characterize this large fluvial lake.

Invasive species

By 2006, the number of reported aquatic invasive species in the Great Lakes basin reached 183. Invasion rates in the Great Lakes are the highest for freshwater ecosystems, with a new invader reported every 28 weeks (Ricciardi, 2006). Invasive species have caused multiple alterations to the structure and functioning of the food webs of these ecosystems. Today, increasing attention is focused on assessing the health of nearshore areas where human uses and alterations are concentrated and have the most noticeable effect on river water quality. The extent of food web decoupling between pelagic and benthic habitats as a result of the invasion by zebra mussels is a cause of growing concern, as production shifts from the water column to benthic zones (Mills et al., 2003). Past focus has been on lake systems, but similar changes in ecosystems are expected to occur in large river systems. Although the ecological impacts of past invaders are known, the food webs of the Great Lakes-St Lawrence ecosystem are in constant flux, coping with the synergetic impacts of new or continuing sources of alterations.

In 2006, the invasive diatom *Didymosphenia geminata* was discovered in the lower St. Lawrence River region. Blooms of this diatom have been associated with changes in the lower food web, which may in turn reduce fish populations by fouling spawning beds (Atlantic salmon, *Salmo salar*, in eastern Québec). Gillis et al. (this issue) studied the response of aquatic macroinvertebrates associated with *D. geminata* blooms and found that the presence of *D. geminata* caused a shift in macroinvertebrate populations by reducing the density of mayflies, stoneflies and caddisflies and increasing the density of chironomids, thereby further decreasing macroinvertebrate species richness, likely due to a loss in food diversity.

To date, *Hemimysis anomala*, the bloody red shrimp, has been found in 45 sites (both lentic and lotic) in the Great Lakes basin. This latest invader was discovered in the Great Lakes in 2006 and has the ability to alter the energy flow by grazing heavily on algae and zooplankton. Using stable isotopes, Marty et al. (this issue) sampled three of the Great Lakes to retrieve information on the ecology of *H. anomala*. Although *H. anomala* was always observed close to shores with similar habitat characteristics (shallow waters, boulders), it may feed on a wide range of food sources, including both littoral and pelagic production. Nitrogen signatures of *H. anomala* were strongly related to carbon signatures and C:N ratios, indicating the importance of food (source and nutrient value) on the trophic position of *H. anomala*. Although more studies are needed to identify the positive and negative effects that *H. anomala* may have on food webs in the Great Lakes, this study indicates that *H. anomala* has a wide trophic niche and is capable of having widespread impacts on the lower food webs of the St. Lawrence River.

Contaminants

The history of human activities along the St. Lawrence has resulted in a legacy of contaminant deposits in sediment deposition areas within the river. Mercury (Hg) is a major contaminant of concern in the St. Lawrence River near Cornwall, ON and further downstream in fluvial Lake St. Francis where elevated mercury levels are present in fish and sediments. Ridal et al. (this issue) carried out detailed investigations of the transfer of mercury to the food web in localized zones of sediment deposition near historical industrial inputs and in reference areas removed from past direct sources. Their study points out the great complexity within the river, with significant differences in food web contamination found even for those zones with similar levels of contamination. They point out that a "one-size fits all" management strategy for contaminated sediment needs careful consideration given unique sediment properties and characteristics for Hg bioaccumulation of each sediment deposition area. Similar contaminated zones likely exist in other areas downstream and across the river in the St. Lawrence River at Massena Area of Concern in Massena, NY where polychlorinated biphenyls and polynuclear aromatic hydrocarbons are the contaminants of concern.

Organic matter cycling in hyporheic zones

Cycling of organic matter in the hyporheic zone (the region underneath streambeds that integrates surface and groundwater) is an important process for rivers but little is known of the mechanisms involved, particularly in large river systems. Two articles examine this issue with a small river system that typifies many of the tributaries that drain into the Great Lakes–St. Lawrence River system. In the first article, Wong and Williams (this issue) examine the sources and seasonal patterns of dissolved organic matter (DOM) in both downwelling and upwelling areas of the hyporheic zone to characterize the quality of the organic matter. Their results suggest that biogeochemical processing within the hyporheic zone results in a DOM pool that is temporally dynamic and which influences the nature of organic matter transported downstream into lakes and rivers.

In the second article on this subject, Febria et al. (this issue) examined the seasonal changes in physicochemistry and bacterial community composition in hyporheic sediments. Seasonal patterns in microbial community composition and environmental parameters were correlated, with temperature most strongly influencing summer communities, DOC having the strongest influence on fall communities, and winter and spring communities being most strongly associated with changes in nitrogen concentrations. The results highlight the complexity of this zone and the need for careful spatial and temporal resolution when characterizing it. Extension of this study to the hyporheic zone of the St. Lawrence River would provide useful insight into nutrient and contaminant cycling.

Water levels and habitat effects

Development of the St. Lawrence Seaway and hydropower project also marked the advent of regulation for flows and water levels beginning in 1960 on Lake Ontario and the St. Lawrence River. The creation of Lake St. Lawrence through removal of the Galop Rapids that served as the natural regulation point for Lake Ontario, and the Moses-Saunders and Long Sault dams, which flooded the Long Sault Rapids, created a new managed hydrodynamic system. Regulation of levels and flows in accordance with the International Joint Commission orders has followed plan 1958-D since October 1963 and its subsequent deviations to manage under extremes. Considerable attention has been given to determining the effect of flows and water levels management on the environment given the recent International Joint Commission Lake Ontario–St. Lawrence River Water Levels Study (International Joint Commission, 2006).

Several articles contributed to this volume revolve in part around this topic. Farrell et al. (this issue) examined pre- and post regulation water level patterns in the St. Lawrence Thousand Islands archipelago (upstream from the power dams) and show how reductions of inter-annual variability, peak levels and periodic lows, lead to a dampening of 30–40 year water level cycles. Several recent investigations (Wilcox et al., 2005; Farrell et al., this issue) examined linkages to water level changes in coastal wetland vegetation structure for Lake Ontario and the Thousand Islands archipelago. In the Lower St. Lawrence River downstream of the power dam, many studies related to this topic area are provided in an Environment Canada synthesis (Talbot, 2006). Here, for the Lower St. Lawrence River and tributaries, the contribution by Hudon et al. (this issue) examined the implications for fish populations of varying temporal scale variations in St. Lawrence River water temperatures and water levels and demonstrated linkages between changes the temporal patterns and fish migration and recruitment in shallow habitats. The effects of water temperature and level, alone or in combination, appear critical to determining successful fish recruitment in shallow riparian areas forming the potentially most important fish spawning and nursery along the St. Lawrence.

Boyer et al. (this issue) examined changes in water levels and hydrodynamics in context with dredging effect and sedimentation in the Richelieu and Saint-Francois tributaries of the Lower St. Lawrence. The modeling by Boyer et al. predicts that the combined effect of changes in tributary discharges and the reduction in St. Lawrence water discharge due to climate change will be an increase in sediment supply compared to the current state. Increased sediment supply will lead to an extension of accumulation zones and deltas. Colonization of these areas by vegetation will have additional impacts on flow and sediments in a wider expanse of the river than initially impacted by increased sedimentation. The authors conclude the regulation of water levels, most notably spring floods, and climatic effects will have influences on tributary sediment dynamics and promote accelerated delta front progression. Since water levels in the Great Lakes are sensitive to climate change (Stow et al., 2008), it follows that water levels in the St. Lawrence River will be accordingly affected by changing climate and its associated impact on geomorphological features (Boyer et al., this issue).

Fish resources

An obvious characteristic of large river ecosystems is their temporal variability, associated primarily with hydro-climatic variations. The variability at both long- (inter-annual) and short- (seasonal and daily) term scales coupled with the longitudinal variation in river geomorphology and habitats largely determines the variability in species population abundance and biological community dynamics. Anthropogenic modifications to the hydrological regime of rivers typically result in altering the natural variability pattern of physical properties and biological responses. Since 1958, river flow of has been regulated (see above) but the paucity of ecological information prior to the construction of the dam makes it difficult to adequately assess the effects of this permanent perturbation on the physical and biological water properties of the ecosystem in this reach of the river Patch & Busch (1984).

Hudon et al. (this issue) examined the temporal trends in water temperature and water levels in the Lower St. Lawrence River over the past 80 years (1919–2007) and the effects of physical variation on fish population dynamics of three fish species (perch, pike, and common carp). Water levels in the lower river dropped by approximately one meter during the 1955–1982 time period, which coincides with major changes in river physiography and regulation. Since 1960, mean river water temperature increased by 1.3°C but the magnitude of changes varied with space and season. The variations in physical conditions directly affected both pike and perch annual recruitment and, in extreme cases as documented for carp, may severely affect spawning success. The possible effect of long-term changes in river hydrology on the observed decline in the American eel populations was investigated by de Lafontaine et al. (this issue) who used daily eel catches by local fishermen in the Lower St. Lawrence River, to construct a first CPUE index for silver eel (adult migrating American eel) abundance for the period extending back to the early 1960s. It revealed a monotonic declining trend since the late 1960s indicating that the decline in spawning stock size preceded that in recruitment in 1980s. While variations in river discharge cause inter-annual variations in eel catchability, the long-term decline is attributed to large-scale mortality factors associated to exploitation rates in upstream sectors and the construction of the hydropower dam.

Looking forward

As with the previous summaries of research on the St. Lawrence River noted in the Introduction, this compilation of research is a prologue to future advances to be made in understanding the ecological functioning of this large and globally significant river. As explained by Twiss (2007), the International Section of the St. Lawrence River has not benefited in the past from full support for research and surveillance, as have its headwaters, the Great Lakes, and reaches of the river in the Province of Québec or downstream of the power dams. Nevertheless, the continued research activities and collaborations, as evidenced in this special issue, provide encouraging signs of sustained interest in understanding and maintaining the ecological integrity of the St. Lawrence River.

Indeed, the US and Canadian federal agencies responsible for water quality in the Great Lakes will, for the first time in 2013, include the International Section of the St. Lawrence River as part of the ongoing coordinated science and monitoring initiatives in the Great Lakes. Such initiatives augur well for continued interest and advances in our understanding of the limnology of this large river system.

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