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Gill and head kidney antioxidant processes and innate immune system responses of yellow perch (*Perca flavescens*) exposed to different contaminants in the St. Lawrence River, Canada

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ABSTRACT

Biomarkers of oxidative stress metabolism and the innate immune response were examined in gill and head kidney tissue of wild-caught yellow perch (*Perca flavescens*) collected from four sites ranging in type and degree of metal pollution in the St. Lawrence River, Quebec, Canada. Sites were ranked as follows: Île Dorval < Îles aux Sables < Îlet Vert < Beauharnois. Biomarker measurements did not correspond completely to the perceived pollution gradient. Total protein content was highest at a site 4 km downstream of municipal effluents (Îlet Vert) exposed to moderate and high levels of heavy metals and faecal coliforms, respectively. Thiol content was highest at the reference site (Île Dorval) with the lowest contaminant levels. Glutathione-S-transferase (GST) activity was highest in fish from the site furthest downstream that was exposed to moderate metal contamination (Îles aux Sables). Glutathione reductase (GRd) activity was high in both gill and head kidney tissue of fish from the reference site (Île Dorval) and highest in the kidney of fish from the most contaminated site (Beauharnois). Catalase activity was highest in head kidney tissue in fish from this latter site. Ceruloplasmin activity was lowest in head kidney from fish collected at the reference site and highest at Beauharnois. Lysozyme activity was lowest in head kidney tissue from fish at the reference site and highest in tissue from fish at Îlet Vert, downstream of municipal effluents. These results suggest that the direction and magnitude of oxidative stress biomarker response and innate immune function biomarker response vary between tissues and among complex mixtures of contaminants, complicating interpretation of results. Results further suggest that bacterial loading, as measured by faecal coliforms, affects the oxidative stress metabolism and the innate immune response.

1. Introduction

Various sources of urban, agricultural and industrial pollution affect the St. Lawrence River, and pose a significant problem for the ecosystem and a health risk to users. Despite primary treatment (physical and chemical) to remove suspended solids in wastewater, water quality deteriorates downstream of the Montreal sewage treatment plant following inputs of heavy

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metals, PCBs, PAHs, and faecal coliforms (Pham et al., 1999; Gagnon and Saulnier, 2003; Marcogliese et al., 2006). Some of these environmental pollutants, especially heavy metals and PCBs, have the potential to affect fish health in the river, specifically eliciting effects on biochemical functions. However, immediate and severe impacts of short-term and low effluent concentrations are not routinely monitored. Previous studies on fish health in the St. Lawrence River include those on pathology (Lair and Martineau, 1997; Mikaelian and Martineau, 1997), contaminant levels (Ion et al., 1997), biochemical and stress responses (Hontela et al., 1992, 1993, 1995), and endocrine disruption (Aravindakshan et al., 2004).

Fish are widely used to evaluate the health of aquatic ecosystems, and biochemical changes among fishes serve as biomarkers of environmental pollution (Jimenez and Stegeman, 1990; Schlenk and Di Giulio, 2002). Bioaccumulation of toxic substances triggers redox reactions generating free radicals, especially reactive oxygen species (ROS) that induce morphological and physiological alterations in fish tissues (Bainy et al., 1996; Varanka et al., 2001). To counteract tissue damage, fish have developed different enzymatic and non-enzymatic defensive mechanisms to protect themselves against oxyradical production (Winston and Di Giulio, 1991; Lopez-Torres et al., 1993). As a consequence, the health of aquatic organisms is linked to overproduction of reactive oxygen species and antioxidant compounds, principal among them being antioxidant defence enzymes (Mourente et al., 2002). ROS such as hydrogen peroxide (H_2O_2) are also produced by the respiratory burst of phagocytes as part of the innate immune response (Bols et al., 2001). Antioxidant enzymes include radical scavenging enzymes, such as catalase acting on H_2O_2, glutathione-S-transferase (GST) which metabolizes lipid hydroperoxides in response to ROS production, and glutathione reductase (GRd) which participates in the turnover of reduced glutathione pools (Filho, 1996; Mourente et al., 2002).

Furthermore, common pollutants such as heavy metals, PCBs, PAHs, and pesticides alter immunological functions of aquatic organisms (Dunier and Siwicki, 1993; Fournier et al., 2000; Reynaud and Deschaux, 2006). Indeed, immune biomarkers may be useful in evaluating effects of exposure to contaminants (Anderson, 1990; Fournier et al., 2000; Rice and Arkoosh, 2002). Lysozyme, a lysosomal enzyme implicated in the inflammatory process, is a non-specific humoral factor acting against parasitic, bacterial, viral infections or other stressful conditions (Bols et al., 2001; Dautremepuits et al., 2004; Fatima et al., 2007). Its activity may be modulated by exposure to metals and other contaminants (Bols et al., 2001). Ceruloplasmin, an acute phase protein (APP) (Bayne and Gerwick, 2001) belonging to the family of multicopper oxidases, is involved in the regulation of homeostasis. Due to its ability to react with and scavenge oxygen species such as H_2O_2, ceruloplasmin also is considered a type of antioxidant protein (Floris et al., 2000). It is considered an indicator of the acuteness of a disease or tissue trauma (Stadnyk and Gauldie, 1991).

Taking into account that enzymatic, non-enzymatic antioxidant and innate immune systems contribute to important biological defences against environmental stress (Lopes et al., 2001), we investigated the effects of various contamination sources at different localities in the St. Lawrence River on these physiological systems. Yellow perch (*Perca flavescens*), one of the most common freshwater fish species in North America, provides a good model to study responses and possible adaptations of local fish populations exposed to diffuse pollution consisting of varying levels of contaminants.

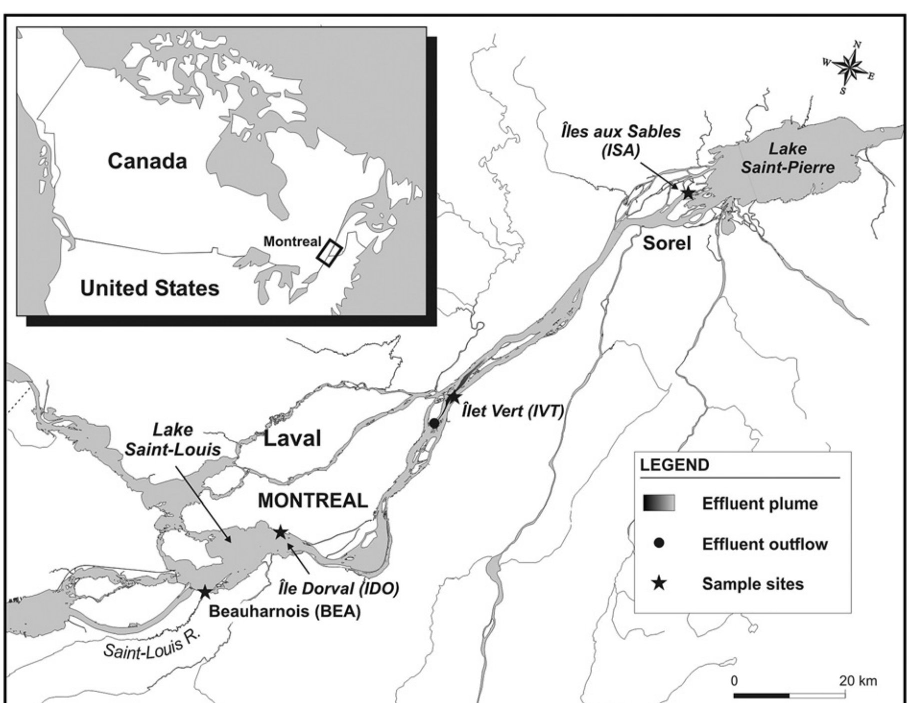

Fig. 1 – Map of the St. Lawrence River, Quebec, showing sampling sites for collections of yellow perch (*Perca flavescens*) in June, 2004.