

## Executive Summary for FY 2002-2003

### <Impacts>

#### Domain Co-Leaders

- Dr. Peter G.C. Campbell, Université du Québec, INRS, INRS-Eau
- Dr. Uwe Borgmann, Environment Canada, National Water Research Institute

#### Projects Included in <Impacts> Domain in FY 2002-2003

Project Title	Principal/Co Investigators	Affiliation
C1 Predicting metal and metal mixture effects in aquatic biota.	Dixon, DG Borgmann, U	Dept. Biology, Univ. of Waterloo NWRI, Environment Canada
C2 Assessing biological effects of chronic metal exposures to fish – laboratory studies.	Wood, CM McDonald, DG	Dept. Biology, McMaster University Dept. Biology, McMaster University
C3 Links between metal burdens in indigenous fish and metal-induced effects at the organism and population levels.	Campbell, PGC Hontela, A Rasmussen, JB	INRS-ETE, INRS, U. du Québec Dépt. Biologie, U. du Québec Montréal Dept. Biology, McGill University
C4 Accumulation and effects of metals in fish-eating birds.	Chan, LHM Scheuhammer, AM	Dept. Diet. Human Nutr, McGill Univ. CWS, Environment Canada
C5 Population and physiological effects of industrial metal contamination on wild fish.	Couture, P Pyle, G	Dept. Biology, Laurentian University Dept. Biology, Nipissing University

#### Progress toward Achievement of the Objectives

In the <Impacts> Domain emphasis has been on research into freshwater ecosystems. The research includes both laboratory studies under controlled conditions and fieldwork along existing metal gradients (downwind and downstream from past/current metal smelters). At the conceptual level, clear linkages exist among the projects making up the <Impacts> program, e.g. influence of metal speciation on metal bioavailability; importance of food and/or sediments as vectors for metal uptake; elucidation of metal detoxification mechanisms; detection of sub-clinical metal-induced effects in indigenous aquatic organisms and their predators. The following research questions were identified in the original proposal and are being addressed in the <Impacts> Domain:

- *How is metal speciation, in the exposure medium and within the exposed organism, related to metal-induced effects at the cellular and individual levels?*
- *Under conditions of chronic exposure, how does food ration (quality; quantity) affect metal toxicity at the organism level?*
- *Can metal body concentrations in exposed organisms provide a better insight into metal-induced effects at the organism and population levels of organisation than obtainable from environmental concentrations?*

*Project C1 Predicting metal and metal mixture effects in aquatic biota (D.G. Dixon, University of Waterloo):*

The main objectives of this project are: i) to determine which methodology most accurately predicts biological effects of single metals (free metal-ion concentrations, alkalinity-pH-DOC-water concentration regressions, or body concentrations), and ii) to determine if metal speciation modelling or body concentration measurements can improve our ability to predict the effects of metals in mixtures. A series of metal mixture 1-week bioaccumulation tests has been completed with the freshwater amphipod *Hyaella azteca* and the compilation of the data and analyses of the samples are ongoing. Metal species and competing inorganic ions were determined by an equilibrium speciation model (MINTEQA2). Binding constants for nickel, hydrogen and calcium to the biological receptor were estimated from the exposures since these were the only factors shown to affect nickel uptake. A Biotic Ligand Model (BLM) for short-term nickel toxicity was developed and toxicity tests were conducted under different exposure conditions to compare observed to expected toxicity. The model showed that BLM modelling was possible for nickel in *Hyaella*. Results from metal bioaccumulation studies conducted using water and sediments collected from five lakes near Sudbury, Ontario and Rouyn-Noranda, Quebec were interpreted for nickel and cadmium. Overall, water chemistry was found to have a substantial effect on cadmium bioavailability from sediment, but only a minimal effect on nickel bioavailability from sediment. Preliminary work began to study the effect of metals accumulated through food on *Hyaella*. This work includes development of culture methods for periphyton, testing of growth and survival of *Hyaella* fed exclusively on periphyton, and preliminary studies on Cd accumulation kinetics by periphyton in preparation for future experiments on exposure of *Hyaella* to Cd-contaminated periphyton.

*Project C2 Assessing biological effects of chronic metal exposures to fish – laboratory studies (C.M. Wood, McMaster University):*

The overall long term objectives of this study are to use laboratory studies to understand and model the chronic impacts of waterborne and dietary Cu, Cd and Zn on the health of fish in the environment with the ultimate aim of developing a BLM for *chronic* toxicity via both exposure routes. There were four important objectives for 2002-2003. The first, which focused on the interrelation between ration quantity and chronic sublethal Cd toxicity in rainbow trout (RBT), is now complete and the results indicate that ration quantity can influence Cd uptake, tissue accumulation and toxicity. Significant progress has been made on the second objective, which was to further develop our understanding further of the influence of dietary quality and quantity on the impacts of both waterborne and dietary metals with emphasis on Cd and Zn, using RBT as a model system. Dietary quality (Ca content) has been shown to reduce the uptake and accumulation of both waterborne Cd and Zn, thereby suggesting the protective role of dietary Ca against waterborne Cd and Zn toxicity. The third objective was to evaluate the effect of sublethal waterborne Cu on feeding pattern and food selection in RBT. This study indicates that sublethal waterborne Cu severely affects food selection, feeding rate and growth in RBT. Finally, the fourth objective was to complete the work on the development of an acute BLM for Cd in yellow perch (YP), a fish species that is endemic to metal-impacted lakes of Eastern Canada (Rouyn-Noranda, Sudbury) and to move on to the development of an acute Zn BLM in the same species. The development of the acute Cd BLM for YP is now complete and the results suggest that the acute Cd BLM framework, originally developed

in model species (RBT), can be extended to YP by simple adjustment of the value of Lethal Cd Accumulation in the gill (LA<sub>50</sub>). The results further strengthen previous studies showing that gill-metal binding characteristics change with acclimation to metal exposure (both by aqueous and dietary route), a phenomenon that is not considered in the present version of BLM and needs further research.

*Project C3 Links between tissue metal burdens in indigenous fish and metal-induced effects at the organism and population levels (P.G.C. Campbell, INRS, Université du Québec):*

This field project has been designed to assess inter-lake variability in the responses of indigenous fish (yellow perch, YP) collected from lakes situated along a metal concentration gradient. Relations are being sought between the physiological condition of the fish and their population status *versus* i) ecological factors (habitat quality, food resources), ii) toxicological factors (ambient [M]) and iii) metal detoxification factors (metallothionein (MT) induction and subcellular metal partitioning). At **INRS**, variations in the efficiency of metal detoxification along a metal concentration gradient and the dynamics of metal accumulation in juvenile yellow perch in the field are being assessed. Inter-lake variability has been analyzed by examining: i) changes in metal partitioning among YP tissues as ambient metal levels increase, and ii) responses of juvenile YP along the metal concentration gradient at the tissue level. In 2002 a full-scale habitat-swap (transplant) experiment to study the dynamics of metal uptake and MT induction in juvenile YP was also carried out. At **UQAM**, the relationship between physiological fitness and metal tissue concentrations in young stages of yellow perch is being assessed. Analysis of physiological data from the Abitibi lakes has been completed. Based on these results, the study has been extended to lakes in the Sudbury area. Thus far, plasma cortisol levels have been measured in all the sampled fish; the other biochemical analyses (*in vitro* cortisol secretion by head kidney tissues, plasma thyroid hormone levels, plasma glucose, liver glycogen) and histomorphological analyses of tissues (gill, thyroid, gonads) are in progress. The gonadosomatic, hepatosomatic indices have been calculated and the statistical analyses are also in progress. It is anticipated that the comparison of physiological, hormonal and population responses in yellow perch sampled from the two regions (Abitibi and Sudbury) will be very important for the validation of the biomarker responses to metals. At **McGill**, in parallel with the field activities described above, studies have been extended to assess the responses of populations and communities to metal impacts by examining lakes in different stages of recovery from historic metal impacts in the Sudbury area. Analysis of benthic samples from Abitibi lakes has been completed.

*Project C4 Accumulation and effects of environmental metals in fish-eating birds (L.H.M. Chan, McGill University):*

The objective of this study is to determine the extent to which environmental metal contamination is causing adverse effects in wildlife populations in Canada. A direct relationship was not seen between Hg exposure and immunotoxicity in common loons, neither *in vivo* nor *in vitro*. Good progress is being made in the field study for comparing fish-Hg levels, and Hg exposure in loons breeding in environments with differing natural background levels of Hg, differing environmental chemistry, and differing levels of

anthropogenic activity, especially metal mining and smelting. A good correlation of Hg/Se was observed in various tissues in common loons. Hg and Se speciation was found to be different in different tissues. All Hg in loon eggs were found to be associated with Se.

*Project C5 Population and physiological effects of industrial metal contamination on wild fish (P. Couture, Laurentian University):*

Significant progress has been made with respect to the objectives stated in the original proposal. The overall objective was to understand the extent of metabolic impairment and the factors influencing growth, reproductive fitness, and physiological condition in wild fish inhabiting metal-contaminated lakes. The specific objectives were: i) to identify and characterise population-level metal effects in wild yellow perch (YP) and other forage fish inhabiting industrially-contaminated lakes around Sudbury, ON; ii) to increase understanding of direct effects (i.e., toxic metabolic effects) *versus* indirect effects (i.e., food web disturbances, investigated by Project C3 in the same lakes) of environmental metal contamination on wild fish condition, growth, and metabolic performance; and iii) to assess the ionic composition and metal contamination of natural YP diets, and to determine if they relate to effects identified in (ii). All sampling required to reach these objectives was successfully completed and most laboratory analyses are complete. Data analysis is underway and will be complete before the start of the next MITE field season.

**Partnerships and Collaboration**

In the <Impacts> Domain, Projects C1 and C3, as well one of the government projects funded by the Network (Project CF1, CF2) with funds from the Mining Association of Canada (EC-NWRI; L. Grapentine), share a common interest in the influence of metals on benthic invertebrates. A common set of lakes has been sampled by all three teams in the Rouyn-Noranda area, and data have been exchanged among the projects. Researchers from Projects B2 and C1 are collaborating on writing a commentary manuscript for *Human and Ecological Risk Assessment* on metal uptake from food in invertebrates, and influence from Project B2 has resulted in the initiation of a new study by a new graduate student in Project C1 looking at the toxicity of metal accumulated from food. Similar links exist among Projects C2, C3 and C5, where the yellow perch has been chosen both as a sentinel species for the field-based research and as a test species for the ongoing physiological and dietary studies in the McMaster University fish toxicology laboratories. Students and researchers from INRS-ETE have profited from the physiological expertise of their counterparts at McMaster University and Laurentian University. INRS-ETE researchers have helped with the metal speciation simulations used by the McMaster researchers in designing their exposure media.