

GRADUATE AND POSTDOCTORAL STUDIES

MCGILL UNIVERSITY



FINAL ORAL EXAMINATION
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

OF

NICOLA CRAIG

NATURAL RESOURCE SCIENCES

**IMPACTS OF DISSOLVED ORGANIC CARBON ON PRODUCTIVITY OF
FISH AND BENTHIC MACROINVERTEBRATES IN NORTH TEMPERATE
LAKES**

Tuesday 29th March 2016
9:15am

MacDonald Stewart Building, Room MS2-022
McGill University, Macdonald Campus

COMMITTEE:

Dr. B. Simpson (Pro-Dean) (Food Science & Agricultural Chemistry)
Dr. M. Humphries (Chair) (Natural Resource Sciences)
Dr. C. Solomon (Supervisor) (Natural Resource Sciences)
Dr. C. Buddle (Internal Examiner) (Natural Resource Sciences)
Dr. S. Jones (Member) (Biology, University of Notre Dame)
Dr. L. Chapman (External Member) (Biology)

Dr. Josephine Nalbantoglu, Dean of Graduate and Postdoctoral Studies
*Members of the Faculty and Graduate Students
are invited to attend*

ABSTRACT

Over the past several decades, increases in concentrations of dissolved organic carbon (DOC) have been observed in many north temperate aquatic ecosystems, a phenomenon known as aquatic 'browning'. However the ecological consequences of this increase are not well understood. DOC from terrestrial sources stain lake waters a dark brown color, and can have strong effects on the physical and biological structure of lake ecosystems. This occurs through its associated light and heat attenuating properties, which reduce thermocline depths, and thus the area of light, warm, and well-oxygenated habitat in DOC-rich lakes. Recent work has shown that fish productivity decreases along a gradient of increasing DOC, however the mechanisms behind this have not been fully explored. Here, I demonstrate potential mechanisms for this loss in productivity by determining how DOC affects zoobenthos, a primary prey item for many fish, as well as how DOC affects fish feeding efficiency and life history strategies.

Through the use of a spatial lake survey, I show that zoobenthos production declines over an increasing DOC gradient, and that this decline is due to limitations in oxygen-rich habitat availability, rather than the previously assumed mechanism of primary resource limitation. As many fish are visual predators, and high levels of DOC may reduce visibility, I then examined how DOC may affect fish feeding efficiency using mesocosm experiments and another gradient-based diet survey. I showed that bluegill (*Lepomis macrochirus*) feeding efficiency is not affected by DOC concentration, suggesting that these benthivores use cues other than vision to detect prey in darker, DOC-rich lakes. The reduction of fish productivity with increasing DOC is likely manifested through shifts in life history characteristics that are important to understand if we are to better manage fisheries with increasing browning. Again using bluegill as a model organism, I show that in low-DOC lakes, fish are able to attain enough energetic resources to reproduce as well as continue to grow after maturity. However, in high-DOC lakes, growth slows after maturity is reached, and so overall reproductive output and maximum size is reduced in these populations.

Currently, the majority of studies focusing on the effects of DOC on consumer productivity are based on spatial gradient surveys, models, and mesocosm experiments. However, browning is a temporal process, and these studies may not accurately reflect how consumers may react to increases of DOC over time. In my final chapter, I describe a whole-ecosystem experiment where we divided a lake in two and increased DOC in one basin, comparing the effects on zoobenthos biomass and productivity to a reference basin, as well as the spatial survey from the first chapter. I show that, contrary to the results of the spatial survey, zoobenthos biomass actually increased with increasing DOC concentrations in this temporal experiment. This result suggests that there may be transitional effects of DOC increases on zoobenthos communities, and that the relationship between DOC and ecosystem productivity may be non-linear. This thesis highlights the need for multiple approaches in order to untangle the complex effects of DOC in lake ecosystems. The observations within will help us better predict how consumers in lake ecosystems may react in the face of future increases in DOC, and how to manage them accordingly.

CURRICULUM VITAE

UNIVERSITY EDUCATION

McGill University, Montreal, Canada. **PhD Renewable Resources**. 2012-present.

Supervisor: Chris Solomon

Thesis title: *Impacts of dissolved organic carbon on productivity of fish and macroinvertebrates in north temperate lakes.*

Queen Mary University of London, London, UK. **MSc Freshwater and Coastal Sciences**. 2010-2011.

Supervisor: Guy Woodward

Thesis title: *Climate change in freshwaters: the effects of temperature on stream structure and functioning from individuals to food webs.*

Queen's University Belfast, Belfast, UK. **BSc (hons) Marine Biology**. 2007-2010.

Supervisor: Chris Harrod

Thesis title: *Spatial and temporal variation among fish communities in the Peruvian Amazon.*

EMPLOYMENT

2016 Freshwater monitoring internship: *Wild Conservation Society, Canada.*

2015 Prey fish dynamics internship: *Ontario Ministry of Natural Resources, Lake Ontario Management Unit.*

2014 Lab & field instructor: *Fish Ecology, McGill University.*

2012 Lab & field instructor: *Fisheries and Wildlife Management, McGill University.*

2011 Research assistant, invertebrate identification: *Queen Mary, University of London.*

2010 Research assistant, European eel population survey: *Queens University Belfast.*

2009 Research assistant, Fish biodiversity monitoring: *Operation Wallacea.*

2006 Research assistant, Forest biodiversity monitoring: *Frontier Madagascar.*

AWARDS

2015 CREATE program internship funding \$8500

2015 UNDERC mentoring fellowship \$6500

2015 Clemens Rigler Travel Award, CCFRR \$210

2014 CREATE program Graduate Excellence Award \$2000

2014 Graduate Excellence Award, McGill NRS \$8000

2014 QCBS Excellence Award \$1655

2014 UNDERC mentoring fellowship \$6500
2014 GREAT Award, McGill NRS \$285
2013 QCBS Excellence Award \$2441
2013 UNDERC mentoring fellowship \$6500
2013 Graduate Excellence Award, McGill NRS \$8000
2013 Graduate Mobility Award, McGill NRS \$480
2013 GREAT Award, McGill NRS \$350
2012 Schulich graduate fellowship \$25,000
2012 Graduate Excellence Award, McGill NRS \$6000
2010 NERC Masters Training Grant £17,000

PUBLICATIONS

In review

Craig, N, S.E. Jones, B.C. Weidel, and C.T. Solomon. In review. Life history constraints explain negative relationship between fish productivity and dissolved organic carbon.

Craig, N, S.E. Jones, P.T. Kelly, B.C. Weidel, J.A. Zwart, and C.T. Solomon. In review. Increased dissolved organic carbon boosts zoobenthos biomass in a whole-lake experiment.

In press

Kelly, P.T., N. Craig, C.T. Solomon, B.C. Weidel, J.A. Zwart, and S.E. Jones. In review. Experimental whole-lake increase of dissolved organic carbon concentration produces unexpected increase in zooplankton biomass and production.

Zwart, J.A., N. Craig, P.T. Kelly, C.T. Solomon, B.C. Weidel, and S.E. Jones. In press. Whole-lake metabolic and physiochemical responses to experimentally increased dissolved organic carbon. *Limnology and Oceanography*.

Published

Craig, N., S.E. Jones, B.C. Weidel, and C.T. Solomon. In press. Habitat, not resource availability, limits consumer production in lake ecosystems. *Limnology and Oceanography*.

O’Gorman, E. J., D. E. Pichler, G. Adams, J. P. Benstead, H. Cohen, N. Craig, W. F. Cross, B. O. L. Demars, *et al.* 2012. Impacts of warming on the structure and functioning of aquatic communities: individual- to ecosystem-level responses. *Advances in Ecological Research* 47:81-176.

