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Oral Presentation

Exposé oral

Submission from the McMaster University and the University of Regina Whitefish Research Group

Mémoire de l'Université McMaster et l'Université de Régina Whitefish Research Group

In the Matter of

À l'égard de

Bruce Power Inc. – Bruce A and B Nuclear Generating Station

Bruce Power Inc. - Centrale nucléaire de Bruce A et Bruce B

Request for a ten-year renewal of its Nuclear Power Reactor Operating Licence for the Bruce A and B Nuclear Generating Station

Demande de renouvellement, pour une période de dix ans, de son permis d'exploitation d'un réacteur nucléaire de puissance à la centrale nucléaire de Bruce A et Bruce B

Commission Public Hearing – Part 2

Audience publique de la Commission – Partie 2

May 28-31, 2018

28-31 mai 2018

Canada

Research Program on Lake and Round Whitefish

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McMaster University

University of Regina

Once-though cooling

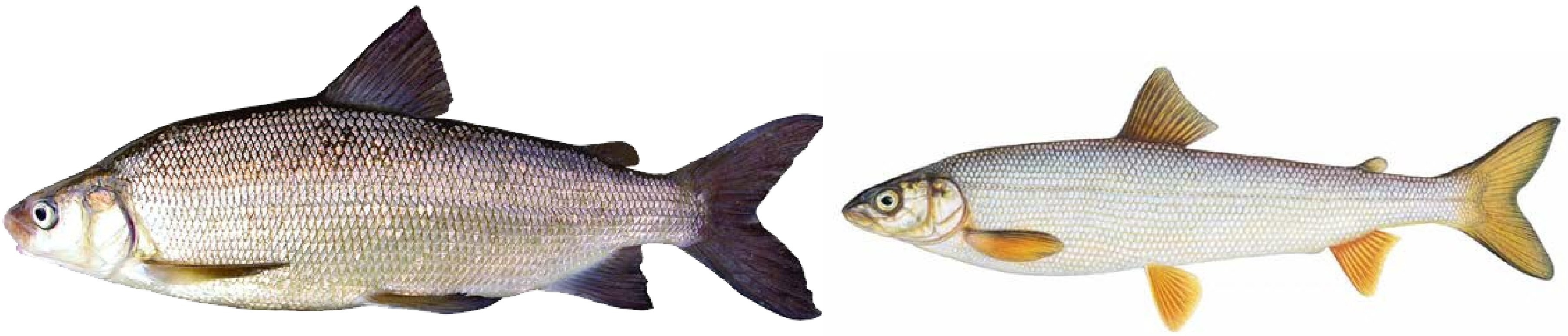
Key Questions

- **Thermal effects:** are there any effects (negative or beneficial) of the Bruce Power thermal plumes from cooling water discharges on the whitefish population(s) in terms of stress response or mortality?

- **Combined stressors:** are there any combined effects (negative or beneficial) of Bruce Power radiological and conventional emissions on the whitefish population(s) in terms of stress response or mortality?

- **Population discrimination:** how many whitefish populations exist in Lake Huron, and is there any likelihood that these populations will be impacted by Bruce Power operations based on spatio-temporal distribution?

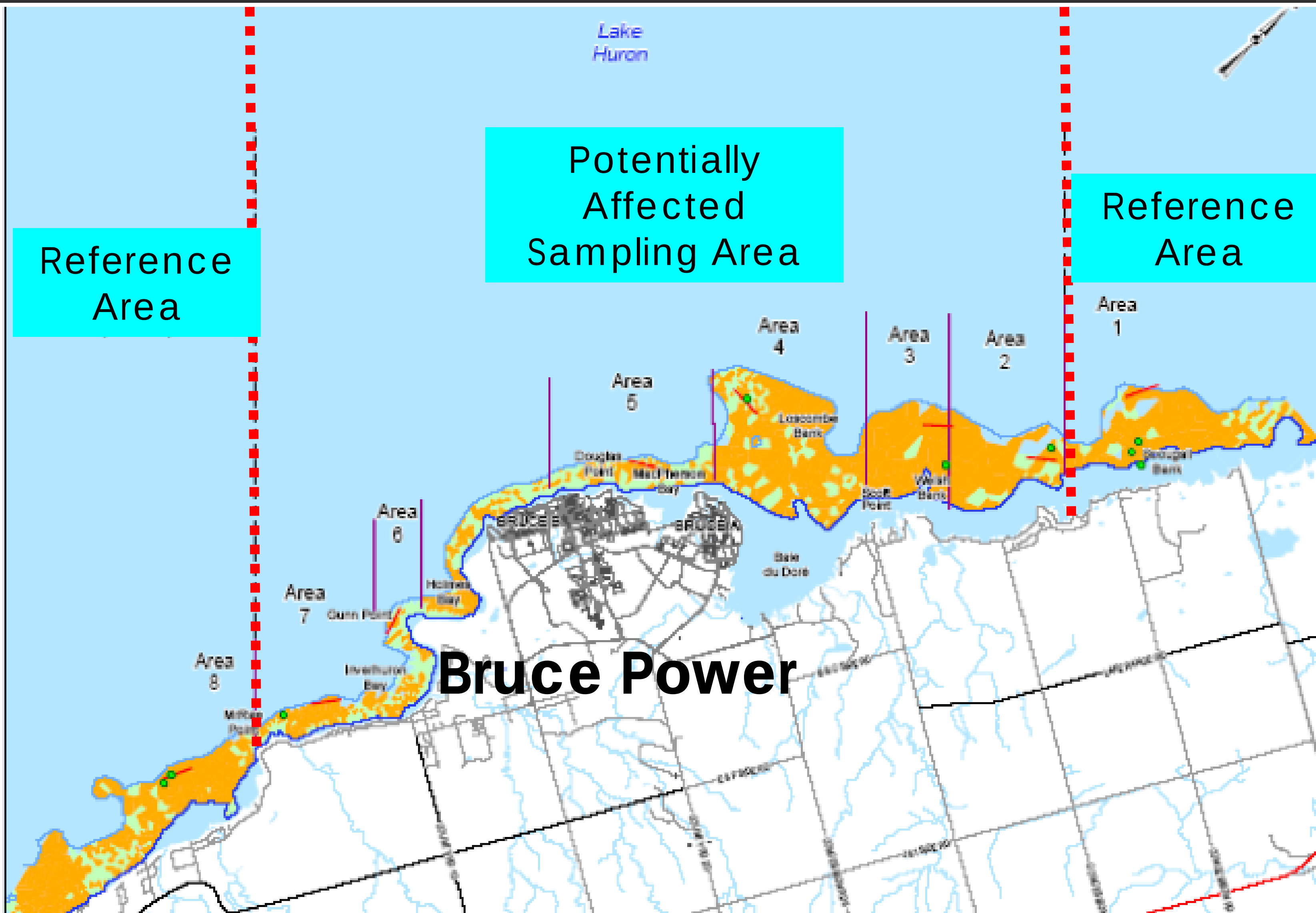
Understanding Thermal Effects



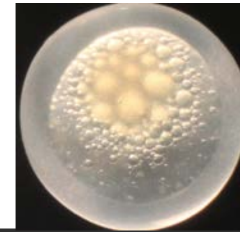
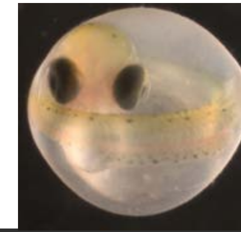
Joanna Wilson and Richard Manzon

Field Incubations

Study Area

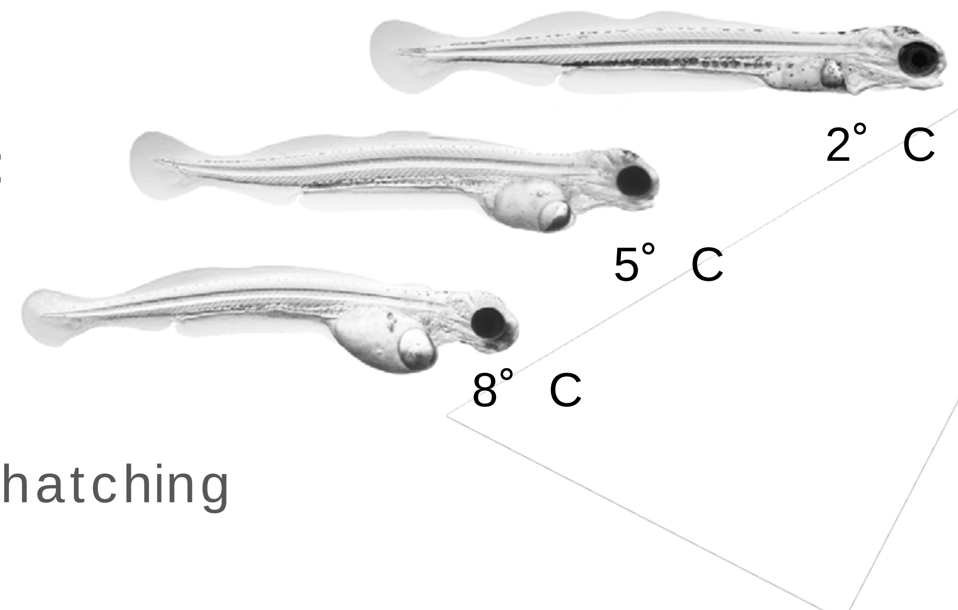

Lake Huron
Potentially Affected Sampling Area
Reference Area
Reference Area
Area 1
Area 2
Area 3
Area 4
Area 5
Area 6
Area 7
Area 8
Bruce Power
BRUCE B
BRUCE A
Baie du Dore
Gunn Point
Inverhuron Bay
Holmes Bay
Douglas Point
MacPherson Bay
Scott Point

Experimental Thermal Exposures

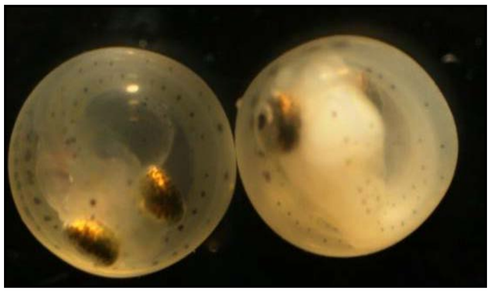



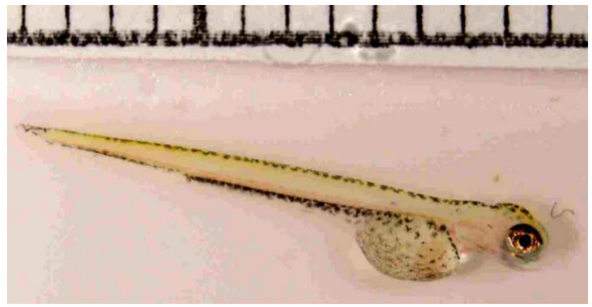

Thermal Stress

- Whitefish embryos are optimized for low temperature
- 0.5, 2, 5, 8 ° C
- Warmer incubation temperature:
  - Increase mortality
  - Decrease growth
  - Decrease time to hatch
  - Alter developmental stage at hatching



Lake Whitefish: Cellular Responses to Heat Shock (HSR)





Heat shock response is a key, protective cellular response

<u>Embryo HSR</u>

- Slow, long-lived

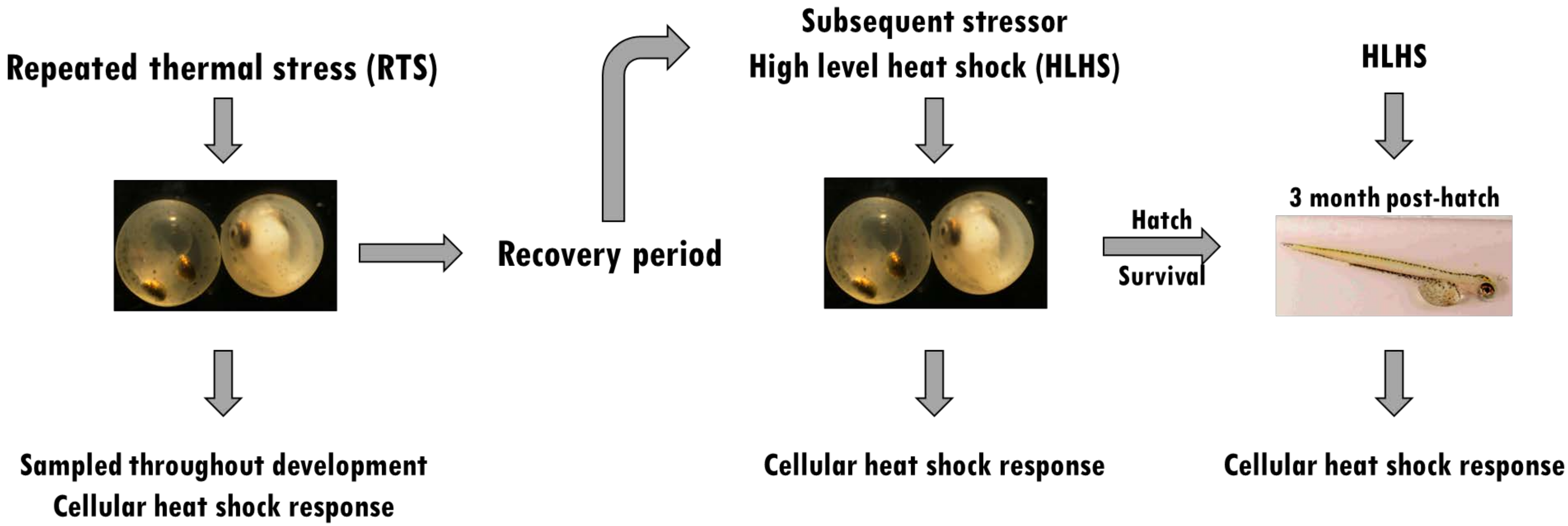
<u>Larval/Fry HSR</u>

- Rapid

<u>Juvenile HSR</u>

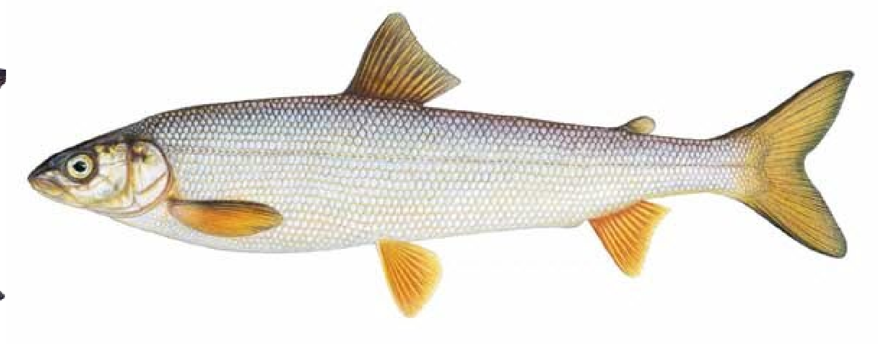
- Acclimation response

Adaptive Potential: Thermal Effluents



- Cellular heat shock response is plastic
- Exposure to mild thermal stress may offer a stronger protective cellular response if a more severe stressors is experienced

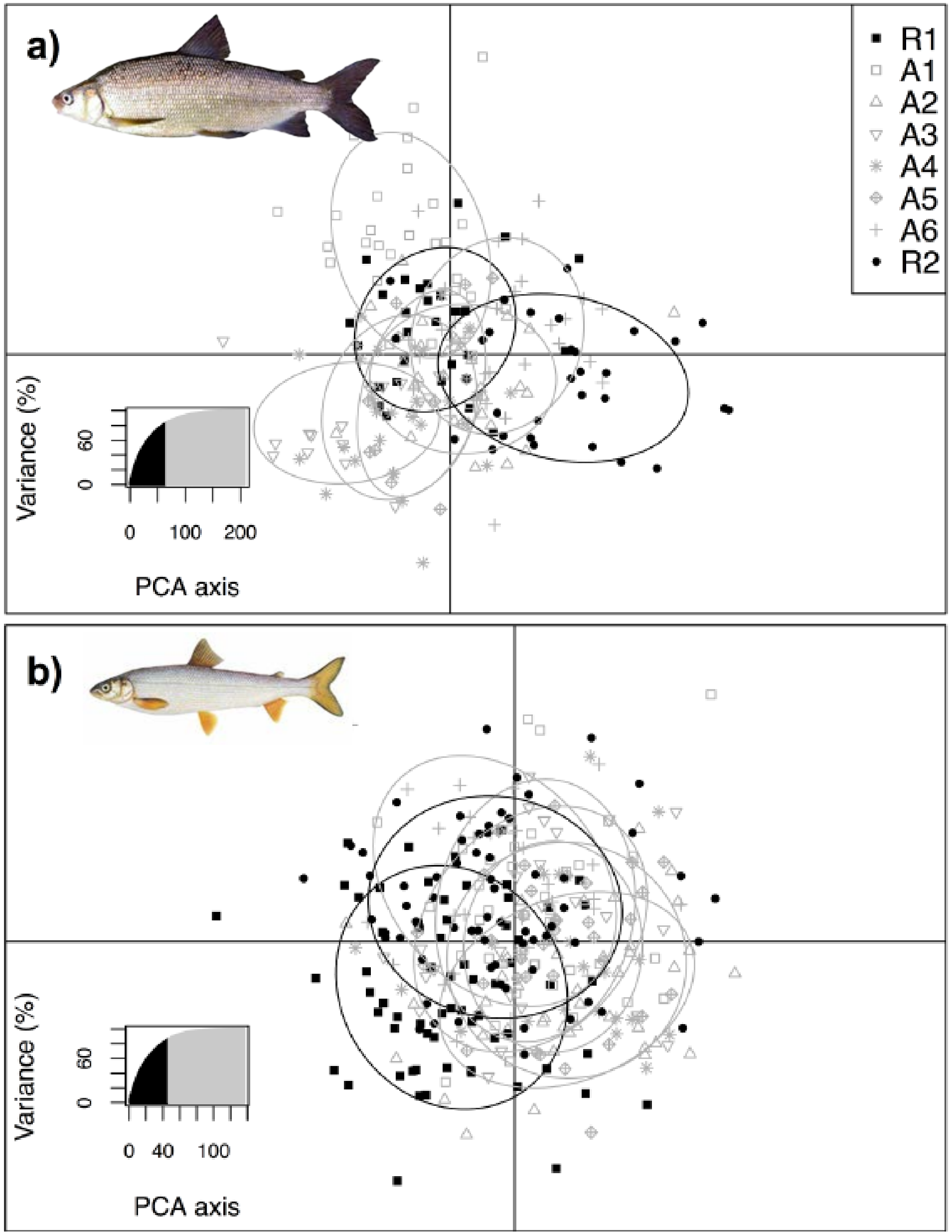
Understanding Population Structure



Christopher Somers

Population Structure: Douglas Point Area

Genetic Markers: Microsatellite DNA



- Fish in R1 & R2 zones **not distinct** from A1-A6.
- Both species same finding.
- LWF potentially more diverse than RWF.

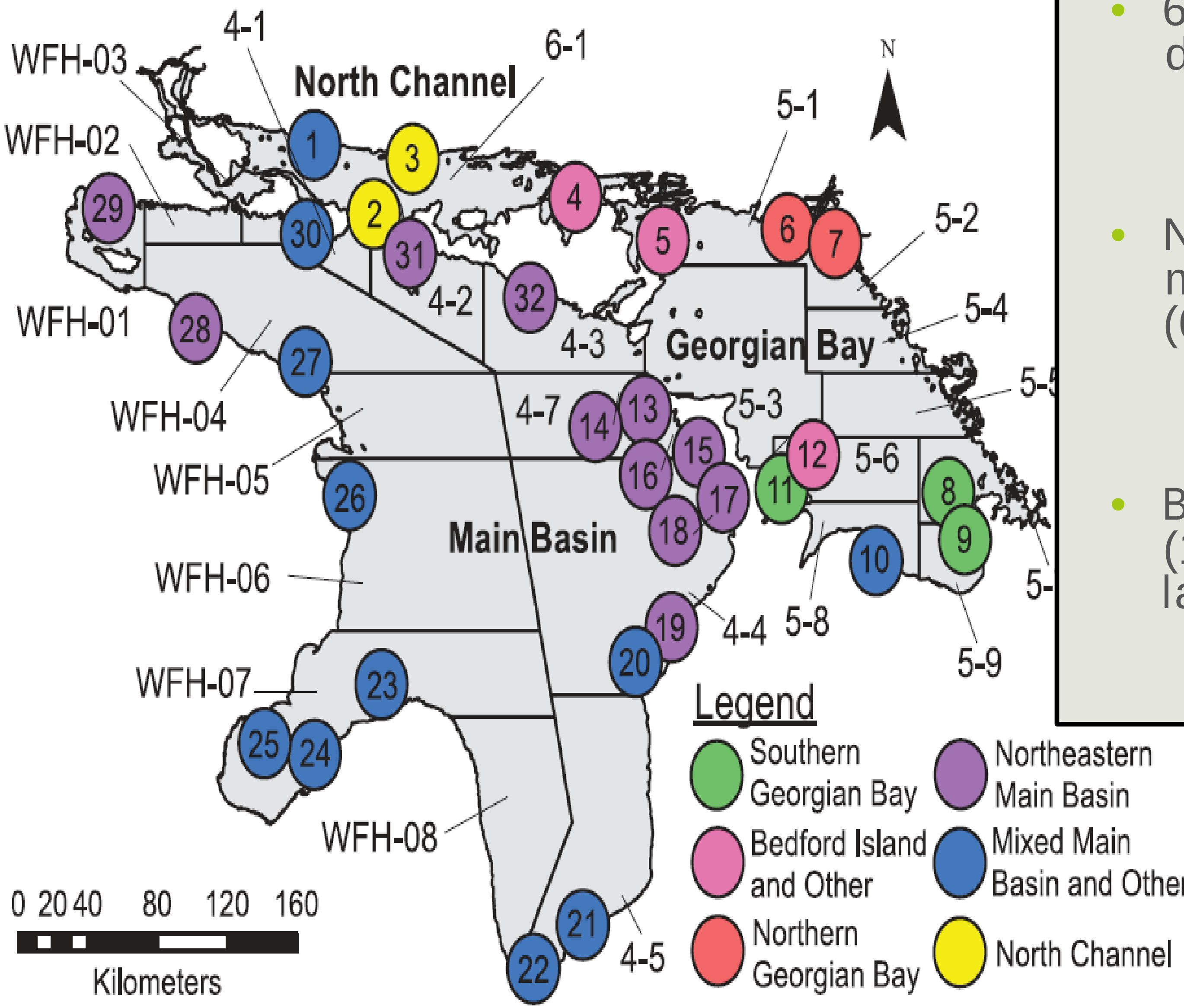
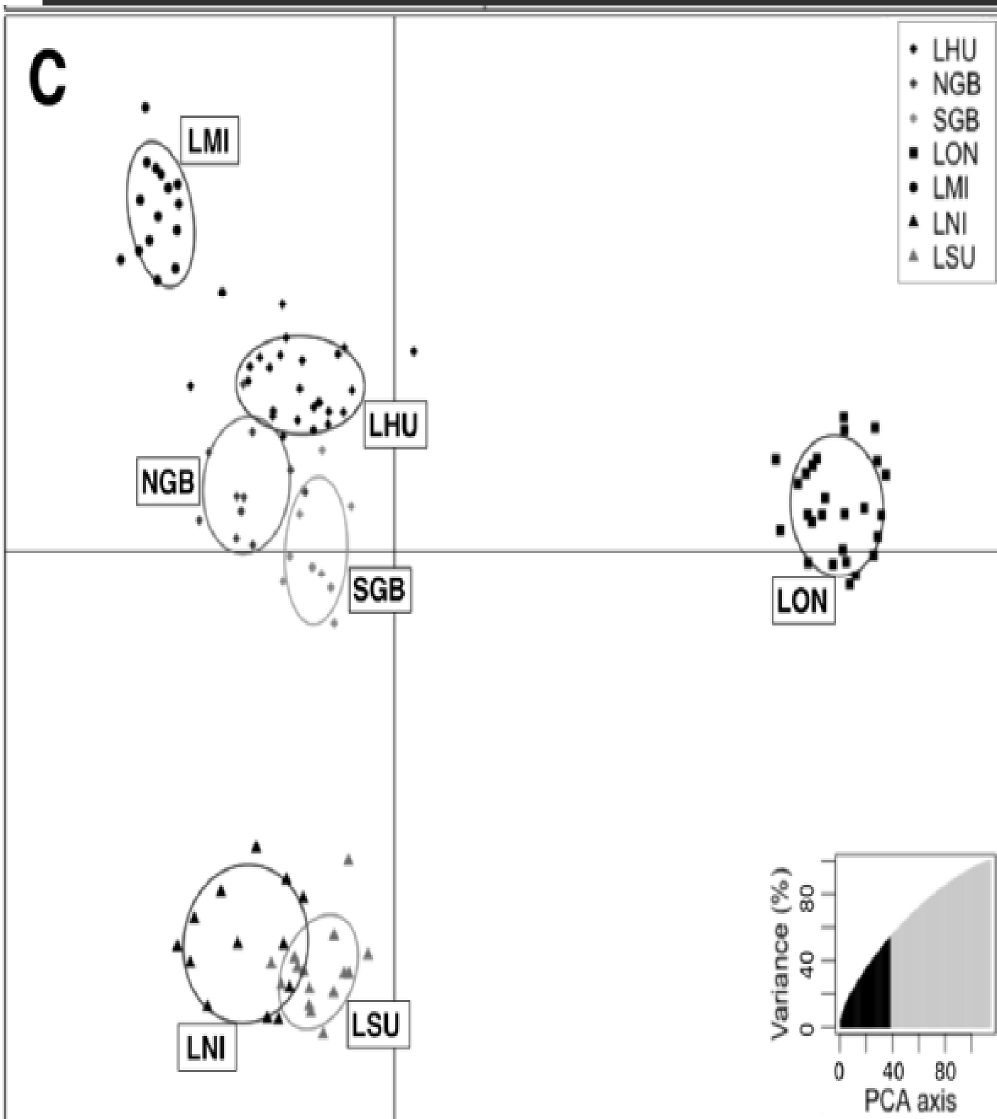


FIGURE 7. Location of isotopically similar spawning-phase Lake Whitefish sampling sites (by color) in Lake Huron according to hierarchical classification analysis. Colors represent the groupings (see legend) shown in Figure 6. Management units (black lines) are shown and labeled for reference.

- 6 isotopically distinct groups.
- Northern GB most distinct (6,7).
- Bruce Power (19,20) part of 2 larger groups.

Round Whitefish Great Lakes:



- Differentiation by lake.
- Ontario and Superior/Nipigon most distinct.
- Sub-structure within Huron / Georgian Bay.

Uncertainties

Thermal & Combined Stressors

- Implications of being a different size or developmental stage at hatch is not clear
- Long-term costs vs benefits to an altered cellular HSR with a change in embryonic thermal history

Population Discrimination

- Boundaries of genetic populations that encompass fish near Bruce Power
- Correspondence between ecological and genetic markers

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- Our Collaborators
- Institute for Environmental Change and Society (UR)

[Information]: Research Program on Lake and Round Whitefish

Regarding: University-lead research on lake and round whitefish development and population biology that is relevant to the proceedings.

Submitted by:

[Intervenor] McMaster University & University of Regina Whitefish Research Group

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3. When asked if you want to replace the existing table of contents, click “**Yes**”.
4. Delete this instructional text when the document is complete.**

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INTRODUCTION

1.1 Background

(a) The Intervenors (Whitefish Research Group): We are a collaborative team of university professors that have been working since 2011 to understand more about Lake and Round Whitefish biology in Lake Huron. Our research program has been funded by a peer-reviewed Research and Development grant from the Natural Sciences and Engineering Research Council of Canada in partnership with Bruce Power. We operate at arms-length from Bruce Power and have generated knowledge and expertise on lake and round whitefish that is relevant to the current hearings. Collectively, we have generated 17 peer-reviewed scientific publications in publicly accessible journals that deal directly with these subject matters (see references).

(b) Research Program Overview: Bruce Power discharges large amounts of warmed water from once-through cooling into the local near-shore environment of Lake Huron. This effluent may also contain chemical anti-fouling agents and small amounts of radioactivity. For some time there has been concern that this cooling water may have a negative impact on fish species that spawn in affected areas in the fall, and in which embryonic development occurs at cold temperatures over a long time period (e.g., lake and round whitefish). In addition, whether or not the effluent from Bruce Power may interact with discrete, local populations of fish was a potential concern. However, prior to our research program, basic scientific knowledge to begin addressing these concerns was lacking. Our program is large and diverse, but it currently has three fundamental pillars that reflect the issues raised here: (1) thermal effects on lake and round whitefish development and stress responses; (2) effects of combined stressors (thermal, radiological, chemical) on lake and round whitefish development; and (3) population discrimination of lake and round whitefish.

1.2 Purpose of Intervention

To provide information on lake and round whitefish research findings that is relevant to ongoing Bruce Power license hearings.

2.0 MAJOR RESEARCH FINDINGS

Our independent research findings are extensive and have contributed to both student theses and peer-reviewed publications. To keep this document concise we provide basic plain-language summaries of findings from each of the three pillars of our program below. The peer-reviewed publications that are the source for these summaries are listed in the References section.

2.1 Thermal Effects on Development and Stress Response

We examined thermal effects for Lake Whitefish in two ways; 1) *in situ* directly in Lake Huron and 2) in the laboratory in experimental apparatus.

We incubated Lake Whitefish embryos *in situ* in chambers on the bottom of Lake Huron in areas associated with Bruce Power cooling water discharge. Fish in the most affected areas had on average a ~10% advancement in development. Embryos incubated directly in the discharge were slightly longer with a smaller yolk area than reference fish, but showed no increase in developmental abnormalities. Temperature in the cooling water discharge averaged a maximum of 3°C warmer than nearby reference locations during the incubation period. In some rare instances the temperature was briefly as much as 8°C higher than reference locations.

In laboratory studies examining thermal effects, we examine the effects of temperature on development in two ways. First, we explored the effect of changing the constant incubation temperature for the entire incubation period. Lake Whitefish hatched earlier and had reduced survival when incubated at a constant 8°C (4-6°C above normal) for their whole development. Lake and round whitefish embryos normally develop in rock-cobble substrate for long periods at 2-4°C. Higher constant temperatures during incubation also resulted in a shorter incubation period, higher yolk area and mass, elevated oxygen consumption and heart rate, and lower body lengths and mass at hatching. Second, we explored the effect of short-term increases in temperature throughout the incubation period. Weekly warm water exposures at several temperatures had no effect on time-to-hatch, survival, yolk mass, body mass, length or head width; more frequent (three times per week) warm water exposures had minimal impacts on whitefish development.

Our research also showed that Lake Whitefish embryos and young of the year juveniles mount a cellular response to heat shock that allowed them to survive 4 hours at 9°C above ambient temperature. This level of heat shock exceeds most changes observed in the temperature loggers placed in the *in situ* incubation near the Bruce Power discharge channel. Lake Whitefish embryos were slower than young of the year juveniles to show a heat shock response, but once it developed, it continued over at least 2 days following the temperature fluctuation. This response suggests that embryos and young of the year juveniles are able to protect themselves from subsequent exposure to heat, and may provide an explanation at the biological level for the observation that survival is not affected by intermittent exposure to heat. Round Whitefish showed no change in survival with regular 1-hour 9°C heat shocks from a constant 5°C base. These intermittent heat shocks exceed the temperature changes recorded by the temperature loggers (about 3°C) from *in situ* incubation chambers near the Bruce Power discharge channels. Temperature changes of the magnitude observed in the vicinity of Bruce Power had no significant effect on the stress response of Lake Whitefish embryos.

CONCLUSIONS

- Thermal effluent from Bruce Power is unlikely to be warm enough or consistent enough to cause mortality of developing Lake or Round Whitefish embryos.
- Lake Whitefish embryos developing within thermally affected areas will hatch (~10%) sooner, and will be smaller with larger yolk reserves.
- Embryonic lake whitefish respond to thermal stress with a protective cellular heat shock response that provides a mechanistic explanation for their ability to withstand temporary thermal challenges.

2.2 Combined Stressor Effects on Development

In laboratory experiments, we exposed Lake Whitefish embryos to constant or variable temperature, as well as one of acute or chronic gamma radiation or chemical stressors (morpholine or sodium hypochlorite). Relatively high doses of chronic radiation compared to background of 0.06-4.4 mGy/day resulted in advanced hatching. Higher doses of acute radiation increased embryo mortality. Morpholine concentrations of 1 or 10 mg/L resulted in increased larval size at hatch. There were no significant effects of morpholine at 100mg/l. From 500-1000mg/L we observed decreased larval size, earlier hatch, and increased embryo mortality. Lake Whitefish embryos were also exposed to a combination of thermal, chemical and radiological stressors. A heat shock administered prior to irradiation had a protective effect on Lake Whitefish embryos. The same heat shock administered prior to exposure to morpholine had no protective effect. A heat shock of 2-hours duration (temperature increase of 3°C or 9°C) administered six hours prior to irradiation decreased embryo mortality caused by radiation by up to 25%. Compared to Lake Whitefish, Round Whitefish are likely more sensitive to morpholine exposure, with developmental and mortality effects starting at 500mg/l. No consistent effects were seen at levels between 0 and 100mg/L. Conversely, Round Whitefish are likely more resistant to low dose radiation than lake whitefish, with a 20% reduction in post-hatch mortality for round whitefish embryos exposed to chronic gamma radiation doses between 0.1 and 0.3 mGy/day. The Bruce Power limit for morpholine is 2.5 mg/L measured at the cooling condenser water duct. Any morpholine released at this location would be rapidly diluted in the discharge channel. Monthly monitoring shows that morpholine levels ranged from below detection limits to a maximum of 1 mg/L; 90% of monitoring results were below detection limits. Mortality effects on embryos in our studies occurred at morpholine doses at least 200 times greater than the current emission limit at Bruce Power. No measurable effects of any kind on lake or round whitefish embryos were seen at doses up to 40 times greater than the limit at Bruce Power.

CONCLUSIONS

- Development and survival of Lake and Round Whitefish embryos was only affected by very high levels of chemical and radiological stressors.
- Environmental exposures of fish to morpholine and gamma radiation in Lake Huron are unlikely to ever approach those required to produce effects seen in laboratory studies.

☐ Chemical and radiological stressors do not act synergistically with thermal stress.

2.3 Population Discrimination

We used genetic and stable isotope analyses to examine the local population structure of spawning-phase Lake and Round Whitefish at different locations in the area of Lake Huron adjacent to Bruce Power (~24 km of shoreline). Genetic markers are used to identify non-random breeding groups, and changes in stable isotope ratios reflect differences in provenance, use of different habitats, and specific prey choices. There was no evidence for distinct genetic groups of Lake or Round Whitefish in zones potentially affected by thermal effluent vs. those in nearby reference areas. Similarly, stable isotope analysis showed no evidence for distinct Lake or Round Whitefish provenance or feeding behavior in this vicinity; there was high resource use overlap between fish in the different sampling areas. However, the isotopic data clearly showed that Lake and Round whitefish occupy separate ecological niches. There was also evidence of more extensive mixing of fish in areas most affected by thermal emissions. We have expanded this population-level research to cover larger geographic areas. On a lake-wide scale, stable isotope analyses showed six ecological groups of Lake Whitefish present across Lake Huron and Georgian Bay. In the area adjacent to Bruce Power, the main basin of Lake Huron could be divided into Southwestern and Northeastern ecological groups, with extensive mixing within each of these groups. Lake Whitefish in the Bruce Power area are split between two much larger ecological groupings that cover a large portion of the main basin of Lake Huron. Continued genetics studies have shown that Lake Huron is potentially the source population for Round Whitefish for Lakes Michigan, Superior and northern Georgian Bay as well as for Lake Nipigon through Lake Superior. Sampling was not wide-spread enough within Lake Huron to draw conclusions regarding population structure within Lake Huron.

CONCLUSIONS

- ☐ Lake and Round Whitefish in thermally affected zones adjacent to Bruce Power are not genetically or ecologically distinct from those in nearby reference areas.
- ☐ Lake Huron and Georgian Bay contain 6 ecologically distinct groups of Lake Whitefish; those in the immediate Bruce Power area are part of two much larger groupings that cover almost the whole main basin of Lake Huron.
- ☐ Lake Huron is an important source of Round Whitefish for other Great Lakes, and likely a key component of genetic diversity in the system.

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Glossary

Stable isotopes – atoms of the same element that differ in atomic mass because of neutrons; used extensively as ecological markers in aquatic studies.

Provenance – origin or source of individuals.

Heat shock response – a molecular reaction by cells to produce proteins that protect vital components from additional damage caused by changing temperature or other stressors.

Ecological niche – all of the components necessary for sustaining an animal; in this case the niche is a proxy measure using stable isotopes, which indicate the habitat, water depth, and dietary components of the fish.