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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Response 2016/015

REVIEW OF MERCURY BIOACCUMULATION IN THE BIOTA OF LAKE MELVILLE

Context

In 2009, the Joint Review Panel that carried out the environmental assessment of the Lower Churchill Hydroelectric Generation Project considered methylmercury bioaccumulation as a potential impact. Fisheries and Oceans Canada (DFO) and other federal and provincial authorities, as well as Aboriginal groups, provided advice to the Joint Review Panel on the extent of downstream bioaccumulation. As a result of this advice, the Panel concluded that methylmercury bioaccumulation in downstream areas could be greater than that predicted by the project proponent, Nalcor Energy. In response to this conclusion and related Panel recommendations, the Government of Canada required Nalcor Energy to carry out additional baseline and post-project monitoring of methylmercury in fish and seals including in areas downstream of the project and into Lake Melville. This monitoring was formally prescribed as a condition of the authorization the Department issued to Nalcor Energy in 2013 under section 35(2) of the *Fisheries Act,* for impacts on fish and fish habitat from the Muskrat Falls hydroelectric dam and reservoir creation.

New information presented in a recently published scientific paper (Schartup et al 2015) may change the understanding of methylmercury transport and bioaccumulation, and as a result, changes to the downstream methylmercury monitoring program may be required. Consequently, in January 2016, the Fisheries Protection Program (FPP) of the Ecosystems Management Branch in the Newfoundland and Labrador Region requested that DFO Science undertake a review of this and other relevant documents with the objectives of providing advice with respect to the following context:

- To provide advice on whether information in the Schartup et al. 2015) paper significantly changes the overall predictions about the potential for bioaccumulation of mercury in fish and seals in Lake Melville as presented by DFO and recognized by the Joint Review Panel during the environmental assessment of the Lower Churchill Hydroelectric Generation Project; and
- To advise whether methylmercury monitoring measures prescribed by DFO downstream of the Muskrat Falls hydroelectric dam should be changed in response to information in the Schartup et al. (2015) paper.

This Science Response Report results from the Science Response Process of February 17, 2016 on the Review of Mercury Bioaccumulation in the Biota of Lake Melville.

Analysis and Response

Objective 1: *Does information in the Schartup et al. 2015 paper significantly change the overall predictions about the potential for bioaccumulation of mercury in fish and seals in Lake Melville as presented by DFO and recognized by the Joint Review Panel during the environmental assessment of the Lower Churchill Hydroelectric Generation Project?*

Schartup and colleagues (2015) examined the amounts, methylation and demethylation of mercury in Lake Melville at two times of the year (June and September). They found significant concentrations of methylmercury in the brackish surface layer near the head of the estuary. Methylation rates are highest in this layer and are reflected in methylmercury concentrations in the plankton. These findings were then used to parameterize a mass transport model of mercury in the estuary. Based on this model and observations of methylmercury release from a few cores of shoreline and upland soils, the authors suggest that methylmercury inputs to the estuary from the Churchill River may increase by 25-200% following flooding of the Muskrat Falls Reservoir.

The DFO advice to the Joint Review Panel regarding potential downstream accumulation of mercury in biota in Lake Melville was based on a study of the extent and duration of elevated mercury levels downstream of the Smallwood Reservoir following its creation (Anderson 2011). Since this study found that estuarine species (Rainbow smelt, Tom cod and Sea trout) did show elevated mercury levels following the creation of the Smallwood Reservoir, it was anticipated that the Lower Churchill development would also result in elevated mercury levels in fish following reservoir flooding. Data for estuarine fish is limited so return time estimates are greater than 20 years for Rainbow smelt and less than 28 years for Sea trout (Table 3 and Fig. 5 in Anderson 2011). There was not sufficient data available at the time to examine spatial variation within the estuary or predict potential effects on seals or other piscivorous mammals or birds. Such effects would depend on diet and site fidelity. This advice was presented to the Joint Review Panel during the public hearings in Happy Valley-Goose Bay in March of 2011.

The paper by Schartup et al. (2015) provides a possible mechanism for the elevated mercury that has been observed in the long-term monitoring data from the Churchill system. Their findings are consistent with current understanding of bacterial dynamics in estuaries and differ from mechanisms of downstream transport proposed by Nalcor Energy during the environmental assessment process.

It should be noted that the methylmercury increases predicted by Schartup et al. (2015) following the flooding of the Lower Churchill are very preliminary and are based on short-term incubations of three upland cores and data from two sampling times for the estuary. In addition, the cores did not include litter or the surface organic layer of the soil. If however the proposed mechanism for methylmercury enrichment in northern estuaries is correct, the spatial extent of the increase and exposure of fish and piscivores would likely correspond to the area of the surface brackish layer in the upper estuary.

Objective 2: *Should methylmercury monitoring measures prescribed by DFO downstream of the Muskrat Falls hydroelectric dam be changed in response to information in the Schartup et al. (2015) paper?*

The Environmental Effects Monitoring (EEM) program proposed by Nalcor Energy and approved by DFO is consistent with the expectation that mercury is predicted to rise in fish and seals downstream of the new reservoir and into upper Lake Melville. Sample sites were selected downstream of Muskrat Falls in Goose Bay and into the head of Lake Melville proper. Power analysis was used to determine the appropriate sample sizes of 30 fish per fish species per area. Baseline data for the monitoring program have now been collected for several years (Nalcor Energy 2015). A preliminary review of the 2015 EEM report suggests that there are a number of areas where the program could be adjusted in light of these findings and our further understanding of processes relating to methylation of mercury in the Lake Melville estuary.

The mechanisms for enhanced methylation of mercury in Lake Melville proposed by Schartup et al. (2015) would seem to indicate that the extent of mercury enrichment in the food chain would be associated with the presence of the nepheloid layer associated with the freshwater inflow from the Churchill River into the estuary. Station locations should be re-examined to ensure that the coverage into Lake Melville extends as far as the expected influence of the river. Alternatives for migratory species and those with lower site fidelity may need to be considered in sample site selection as these species may spend only part of their time in affected areas.

Figure 1 of Schartup et al. (2015) shows that in Lake Melville, the brackish layer associated with the outflow of the Churchill River extends almost to the end of the eastern portion of Lake Melville before the Narrows and that elevated total mercury and dissolved organic carbon (DOC) levels are found in this layer. The current sample sites for the monitoring program only extend to the western portion of Lake Melville (Figure 1). If the mechanisms proposed by Schartup et al. (2015) are correct then the full spatial extent of downstream effects would not be captured by this program. A sample site in eastern Lake Melville should be added to the monitoring program to ensure that the spatial extent of potential effects is well quantified.

Water column mercury, particulate organic carbon (POC) and DOC should also be monitored throughout Lake Melville to ensure that the distance downstream of any effects is well quantified, that observed changes in mercury in biota are explained and that the monitoring program adequately captures the full extent of potential effects.

Mercury levels generally increase with size of the individual for a given fish species. Appropriate sampling protocols therefore require that fish sampled for each species represent the range of sizes found in the population. The approved monitoring program (Nalcor Energy 2012) references Scruton et al. (1994) for the sample protocol. Note that this reference is not included in the reference section of the monitoring program. In addition, this paper does not explicitly refer to the length stratified protocol they followed. A more appropriate reference would be French et al. (1998). As in French et al. (1998), the methods section in the monitoring report should include a table of the target lengths for each species of interest.

Power analysis upon which the monitoring program is based suggested an appropriate sample size of 30 fish per species per area. It appears from the appendices in the 2015 baseline monitoring report (Nalcor Energy 2015) that these numbers have been obtained by pooling data for fish from all the stations in Goose Bay and Lake Melville areas. This will not allow comparisons among stations or an assessment of the spatial extent of elevated mercury in the estuary should it occur.

Liver and muscle tissue from Ringed seals were also included in the monitoring program however specimens were collected on an opportunistic basis from the annual harvest locations, and not at specific sites. The variability in tissue mercury levels in the seals is quite high and does not appear to be related to age (Table 3.38 in Nalcor Energy 2015). Factors that may be affecting such variability, such as sample location, gender and diet (using stable isotopes), should be examined to determine how best to sample the seals to ensure that the hypotheses proposed for the monitoring program are testable. Consideration should be given to sulphur or other isotopes that may aid in distinguishing estuarine food sources.

Interannual comparisons of mercury levels for each species have been reported using mean mercury levels. This may not be an appropriate basis of comparison since mercury levels in fish usually increase with the size of the fish. Mercury levels in a standard length fish are generally preferred for this purpose. This ensures that even if the fish sampled in each year differ in size the mercury levels are comparable. Size mercury relationships should also be reported to demonstrate that the mercury levels in standard length fish are calculated from representative samples and that the data respect the assumptions of parametric analysis. Similarly, seal sampling should use a size/age stratified protocol.

Conclusions

The mechanisms for increased methylation of mercury in estuary Lake Melville postulated by Schartup et al. (2015) provide an explanation for the elevated mercury observed in fish from the estuary following the creation of the Smallwood reservoir (Anderson 2011). The advice that the creation of new reservoirs on the Churchill River would result in similar effects, provided by DFO to the Joint Review Panel, was based on these observations. This new study thus supports DFO's original advice.

The EEM program proposed by Nalcor Energy and approved by DFO is consistent with the expectation that mercury is predicted to rise in fish and seals downstream of the new reservoir and into upper Lake Melville. The findings of Schartup et al. (2015) and Nalcor Energy's baseline studies (2015) suggest a number of improvements to the EEM program.

As per the 2013 *Fisheries Act* Authorization, baseline studies of mercury in fish and seals in Lake Melville have been carried out since 2010 and 2011, respectively. In addition, information was collected between 1999 and 2009 in preparation for the environmental assessment process. All results should be combined and reviewed and monitoring protocols adapted to ensure that the EEM program will provide the necessary information on the post-impoundment presence, extent and duration of elevated mercury in fish and seals into Lake Melville. The review should consider the following:

Changes to the EEM Program

- that sample sites are consistent with the spatial extent of methylmercury enrichment suggested by the mechanisms for methylation proposed by Schartup et al. (2015). This would include at least one sample site in the eastern part of Lake Melville;
- that sample sizes are adequate given the observed variability in tissue mercury, particularly for Ringed seals;
- that fish from each site are sampled by a length stratified protocol and seals by age/size;
- that stable isotope data be used to determine if the variability in mercury levels in the Ringed seal samples is related to diet or other factors such as age, size or site fidelity. Consideration should be given to sulphur or other isotopes that may aid in distinguishing estuarine food sources; and
- that water column mercury, particulate and dissolved organic carbon (POC and DOC) in Lake Melville be included in the EEM program. Water column profiles should include samples from the nepheloid and near bottom layers.

Changes to the Reporting

- that mercury levels in each fish species are reported on a site by site basis;
- that mercury levels for each fish species are reported on a standard length basis and;
- that plots of length vs. mercury are included in the report to ensure the validity of the standard length comparisons.

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Appendix

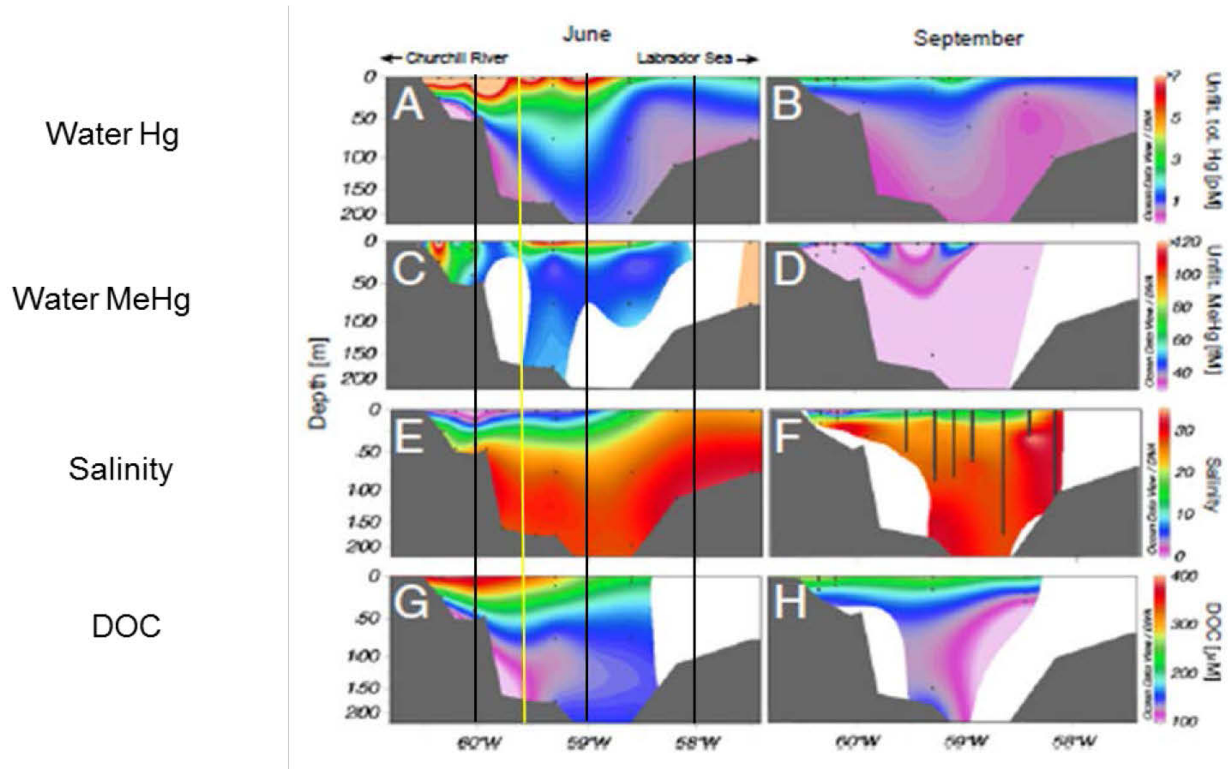

Figure 1. Cross-sectional view of total mercury (Hg), methylmercury (MeHg), salinity, and dissolved organic carbon (DOC) concentrations in unfiltered seawater in Lake Melville, extending from the freshwater inputs on the left (Churchill River) to outer marine regions extending into the Labrador Sea on the right. The yellow vertical line depicts the current extent of EEM Plan sampling in Lake Melville (adapted with permission from Fig.1 - Schartup et al. 2015).

This Report is Available from the

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